A Survey of Aquaculture Enterprises of Quebec in 1978

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A SURVEY OF AQUACULTURE ENTERPRISES OF QUEBEC IN 1978

by

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"J'en fis un pour éviter l'oisiveté, entouré de fossés pleins d'eau, dans lequel il y avait de très belles truites que j'y avais mises et où descendaient trois ruisseaux de fort belle eau courante. Je fis aussi un petit réservoir pour y mettre du poisson d'eau salée, que nous prenions au besoin".

Oeuvres de Champlain,
Tome III, Chapitre XI.

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ABSTRACT

Hansen, Lars, Paul L. Montreuil, and Jean-Denis Dutil. 1980. A survey of aquaculture enterprises of Quebec in 1978. Can. Tech. Rep. Fish. Aquat. Sci. 967: 98 pp.

Little information is presently available on many aspects of the fish culture industry of Quebec. The present survey was undertaken in order to assess the industry; to provide a physical and environmental description of installations; and to identify those areas where research, services and assistance would be most beneficial. A comprehensive questionnaire was sent to 165 licenced commercial hatchery operators, of which 122 returned full responses. 84 fish culture enterprises were visited at least once by the survey team.

From its beginnings, the development of the fish culture industry in Quebec has been closely linked to that of private fishing clubs. The recent termination of most leases to these clubs has forced the industry to modify its production. Further modification will result from the fish-pond industry, the growth of which has received an effective stimulus from new assistance programmes promoted by the Quebec Department of Agriculture.

Twenty four species have been cultured in the past. Speckled trout is presently the most popular, but rainbow trout has been steadily growing in favour, judging by the number of eggs purchased. Regulations relating to the marketing of rainbow trout are more permissive than those applying to speckled trout.

Heaviest mortalities occur amongst alevins, with losses frequently in excess of 75%. The most frequent causes include excessive temperatures (both high and low); insufficient dissolved oxygen, particularly in systems supplied by well water; high nitrite-nitrogen concentrations where water is recycled. Ferric and ferrous hydroxide precipitates and ferric hydroxide flocs produced by ferruginous bacteria both caused gill problems and severe mortalities. Fish samples taken for pathological studies, in some instances, also revealed viral infections (IPN) and myxobacterial infections, particularly furunculosis.

Qualified scientists and technicians are urgently needed to assist in site selection, design of installations, and disease prevention, diagnosis and treatment.

While springs are the most frequently used water source, lakes supply the largest volumes. Surface waters are the most hazardous type of supply, due to their high vulnerability to upstream activities. New techniques coupled with a better understanding of the fishes physical and biological requirements have led to a more intensive use of water, and hence to an increased nutrient load in the water. The whole area of water treatment warrants more attention than it has received in the past, especially where recycling is envisaged as a means of conserving energy - a consideration of some importance in this climate. Fundamental research should also be carried out in the fields of stock selection and genetic improvement, disease incidence and treatment, prepared feed formulations better adapted to the requirements of fish reared under the conditions which prevail in Quebec, and technology adapted to this environment.

This report also includes an historical review of fish culture in Quebec, an outline of related Federal and Provincial regulations, a list of organisms involved, and a physical description of special aspects of some fish culture installations.

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Remark: This report is also available in English (No 967).

FOREWORD

There are few publications concerning private pisciculture in Quebec. The annual reports of the Hatcheries Division of the Ministère des Loisirs, de la Chasse et de la Pêche (Anonymous 1960-1978) are the main source of information presently available and these have only recently started. They include information on private operations, generally limited to licencing, production and sales. Furthermore, the statistics supplied by the Hatcheries Division are considered by many as underestimations because of a suspected reluctance of some operators to supply accurate figures (Asselin et al. 1976; Ayles and Brett 1978). Lack of information concerning private pisciculture presents problems to planners, legislators, researchers and entrepreneurs attempting to assess the industry and their own programs.

The present report provides a physical, economic, geographical and environmental description of private fish hatcheries in Quebec. Limiting factors and problems facing fish culturists are also identified. It is hoped this will supply the industry and concerned groups with some of the information they need to develop and refine their policies. Similarly, it is hoped it will help in the establishment of research programs designed to assist aquaculture development.

The information presented in this report has been acquired by a variety of means: literature survey, questionnaire survey of private hatcheries, site inspections involving pertinent tests on water quality and physico-chemical characteristics, fish sampling, pathological examination, personal interviews with owners and managers. An attempt was made to make the site inspections as useful as possible to the operators. All results were conveyed to them, as well as practical suggestions where warranted. This contributed substantially to gaining the confidence of the hatchery operators.

INTRODUCTION

HISTORY

Quebec's introduction to fish culture was in 1857 when Richard Nettle, Superintendent of Fisheries for Lower Canada, became the first Canadian to artificially fertilize and hatch native salmonids. Two years later, John Holliday started a private salmon hatchery on the Moisie River, thereby establishing the first commercial aquaculture installation in the Province. Shortly after 1867, the federal government created the Fish Culture Division which until 1915 established and operated 9 fish culture facilities in Quebec. In 1915, federal installations dealing with the stocking of inland waters were transferred to provincial authorities. All others were transferred in 1922. Since then the provincial government has operated at least 12 hatcheries.

In 1980, there are six provincial fish hatcheries, operated by the Ministère des Loisirs, de la Chasse et de la Pêche: Tadoussac (1875), Gaspé (1875), Cantons de l'Est (1904), Laurentides (1934), Anse Pleureuse (1973) and Lac des Ecorces (1973). Table 1 provides a list of the species cultured in Quebec and Figure 1 summarizes the history of provincial government hatcheries. The reader is referred to Appendix A for information on introductions of exotic salmonids within Quebec.

RECENT DEVELOPMENTS

Department of Fisheries and Oceans, Canada (DFO)

The Department of Fisheries and Oceans maintains its longstanding interest in aquaculture in Canada and recognizes its potential. Several pilot projects in the field have been sponsored across Canada and there is also an acknowledgment of the need for more research on many aspects (Pritchard 1976). It was in order to address these needs, that the Quebec Region of the Department of Fisheries and Oceans undertook this study.

The Department is particularly concerned with the propagation of fish diseases. It is responsible for the application of the Fish Health Protection Regulations, made under the Fisheries Act of Canada. The Regulations are designed to prevent the propagation of disease agents through certification and control of movement of products into and throughout Canada.

Ministère des Loisirs, de la Chasse et de la Pêche du Québec (MLCPQ)

Since 1914, the MLCPQ or one of the departments which preceded it, has been responsible for the stocking of freshwater fishes within the Province (Table 2). This mandate is the reason for the MLCPQ's concern with private hatcheries. Private hatcheries have only recently started selling substantial quantities of fish for purposes other than the stocking of private or leased fishing waters.

Prior to the late 1940's, private installations were non-profit organizations run by fish and game clubs or associations for the purpose of stocking their own waters. By the end of the forties, hatcheries appeared as commercial ventures and in 1955 there were eight commercial hatcheries in operation.

In 1969, the Hatchery Division of the MLCPQ became responsible for issuing permits to private hatcheries by virtue of the Wildlife Conservation Act of the Province of Quebec. Three licence categories were introduced in 1971 to differentiate between commercial hatcheries, private non-profit hatcheries, and non-commercial fish ponds. A staff

was assigned to licencing and inspection of private hatcheries in 1974. Two years later, the Hatchery Division also became responsible for the administration of the Fish Health Protection Regulations in Quebec.

From 1975 to 1977, financial assistance was provided to the Association des Pisciculteurs du Québec (APQ) to support a permanent secretariat. During those years, six hatchery operators were sent to France to visit large scale commercial hatcheries. Also, the MLCPQ, in collaboration with the former Ministère de l'Industrie et du Commerce du Québec, sponsored a feasibility study of commercial trout culture in Quebec (Asselin et al. 1976).

In 1978, the MLCPQ brought about several changes through amendments to the Quebec Fishery Regulations. These include the establishment of piscicultural zones (Figure 2), the definition of new license categories and legalization of the sale, throughout the year, of speckled trout (Salvelinus fontinalis) from fishing ponds (Appendix B). Furthermore, leases to private hunting and fishing clubs were not renewed. Clubs had been major purchasers of trout for stocking. So, the MLCPQ has committed itself to making compensatory purchases from the affected hatcheries for three years, or until local conservation organizations (Zones d'exploitation contrôlée) are established. These ZEC's will eventually be responsible for the stocking and managing of the sport fisheries within the limits of their territory. Finally, the MLCPQ came to an agreement with the former Ministère de l'Agriculture du Québec about their respective jurisdiction over aspects of commercial fish culture (Appendix C).

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ)

The concept of supplementing farm income through the culture of fish in farm ponds has interested the MAPAQ since 1972. In that year, a feasibility study was undertaken by a private consultant. In 1974, a biologist was hired and in 1975, farmers were given access to financial assistance for the construction of fish ponds. The agreement signed with MLCPQ in 1978 (Appendix C), gives the MAPAQ jurisdiction over most aspects of the production of fish for human consumption. In 1979, cultured fish became officially recognized as a farm product, thereby enabling hatchery owners to take advantage of assistance programs available to farmers.

The fisheries directorate has in recent years taken an interest in aquaculture in Quebec. In 1976, it co-sponsored a study with the MLCPQ (Asselin et al. 1976). At present, it is involved in pilot experimental projects of shellfish culture in the province.

Ministère de l'Environnement du Québec (MEQ)

This department, formerly "Services de Protection de l'Environnement", is responsible for the enforcement of the Environment Quality Act. Recently, the MEQ has become concerned with the pollution potential of private fish hatcheries and it is presently attempting to establish environmental standards for aquacultural enterprises. New hatcheries are to have settling basins and the MEQ reserves the right to require any further modifications deemed necessary (Appendix B).

Ministère de l'Energie et des Ressources du Québec (MERQ)

According to the Quebec Water Courses Act, the MERQ requires that plans of any hydraulic construction be approved and that all new constructions and modifications be inspected and approved by their engineers (Appendix B).

Addresses of government departments involved in regulating and licencing aquaculture operations are listed in Appendix E.

L'Association des Pisciculteurs du Québec (APQ)

The APQ is an association of private fish hatchery owners established by 15 operators in 1965. By 1972, there were 130 members and its newsletter started appearing regularly. From 1975 to 1977, the APQ received three grants from the MLCPQ which enabled the Association to establish a permanent secretariat. The Association also lobbied for changes in regulations concerning private fish hatcheries. Following the interruption of the grants in 1978, membership dues were raised and this resulted in a dramatic drop in membership. A new bulletin "la Pisciculture Québécoise" now replaces the original newsletter and the APQ shows signs of revitalization.

La Co-opérative Québécoise des Pisciculteurs (CO-OP)

The CO-OP was formed in 1975. By 1978, there were 22 members, and its membership was rapidly increasing. In 1978, the CO-OP received a grant from the MAPAQ to enable it to establish a permanent office with a full-time manager. The Cooperative initially concerned itself with supplying feed and equipment to its members. It is expected that by 1981 at least 240 tons of trout will be marketed through the CO-OP.

METHODS AND MATERIALS

PLANNING OF THE SURVEY

An extensive review of the literature and published reports relating to aquaculture in Quebec

revealed major information gaps. These constituted the basis upon which a detailed questionnaire was drafted. This draft was modified and refined following discussions with representatives of public and private agencies concerned with fish culture. The reader is referred to Appendix D for a copy of the questionnaire. Pertinent references are included in Appendix A and listed in the bibliography.

QUESTIONNAIRE

The questionnaire was divided into six sections. The information requested in each section was as follows:

Identification: Name and location of operation, ownership and employees.

Section I: Description of stocks reared and of production.

Section II: Operational data: causes of loss, treatment of diseases and feeding.

Section III: Water supply, treatment and utilization.

Section IV: Technical description of physical plant.

Section V: Assessment of technical and economic efficiency of operation, and desiderata.

Section VI: Comments and suggestions proposed by operators.

The complete questionnaire was mailed to the managers of 165 hatcheries, the total number of operations with commercial licences in 1977 and 1978. A number of 1977 licencees did not renew their permits whereas some new applications were made in 1978. This report summarizes the information obtained from 122 active fish rearing installations.

The questionnaire was completed either by the visiting team (84), by the hatchery operator (15) or by telephone interview (23). Those completed by hatchery operators or by telephone were a shortened version of the original questionnaire, which omitted questions 2 and 3 of Section II, and all of Section V. It was felt that the shorter form would be more likely to encourage response than the more complex long form (Appendix D).

SITE VISITS

The survey team visited 84 installations from May 5 to September 14, 1978. These visits permitted a detailed examination of the facilities, culture systems and features of special interest at each site, including the acquisition of a fairly complete pictorial record illustrating the salient features of the industry in Quebec. Also, collection of biological specimens and field analysis of water samples could be carried out. Lastly, visits permitted interviews with the owner or manager and completion of the survey questionnaire.

Biological samples

These consisted principally of pathological specimens collected for later identification or diagnosis. Whole fish were either frozen or preserved in 10% formalin. Altogether, 19 lots were collected for viral (2), bacterial (10) or parasitological (15) determinations, some lots being subjected to several tests.

Bacteriological inoculations were made on site, using as primary isolation medium, either trypticase soy agar with 0.1% tyrosine (TSA & T) or cytophaga agar. Subsequent bacteriological and parasitological examination, culture and identification were carried out in our laboratory in Quebec City. Frozen specimens collected for viral examination (I.P.N.), were sent to the Fish Health Unit laboratory of the Department of Fisheries and Oceans in Halifax, N.S. In a few cases, bacteria isolated and identified in our laboratory were sent to the Département de Microbiologie de l'Ecole de Médecine Vétérinaire (Université de Montréal) in St-Hyacinthe, or to the Laboratoire de Pathologie Vétérinaire du Ministère de l'Agriculture, des Pêcheries et de l'Alimentation in Rock Forest, Québec, for confirmation and information.

Water tests

At each site, a portable field laboratory unit was set up in a convenient, sheltered location. Samples were collected in sterile bottles and particular attention was paid to the routine sterilization of containers, equipment, boots and hands to reduce the risk of cross-contamination by accidental transport of pathogens from one hatchery to another. Table 3 lists the tests carried out, the methods and apparatus used, and their precision.

Tests for ammonia, nitrite and nitrate nitrogen, soluble iron and orthophosphate were carried out with a Bausch and Lomb Spectronic mini 20 portable spectrophotometer, using Bausch and Lomb Spectrokit reagent systems. Alkalinity, hardness, chloride and carbon dioxide were also determined with Bausch and Lomb Spectrokit reagent systems. Methods and techniques followed were as recommended in Bausch and Lomb's Water Technology manual (Bausch and Lomb 1974). A number of dissolved oxygen readings obtained with Bausch and Lomb kits were low compared to those obtained following the Winkler method. Consequently, a YSI Model 57 dissolved oxygen meter was used for most of these tests. Temperatures were determined either with the YSI meter or with a pocket thermometer (range -10 to 110 C); the accuracy of both meters was checked periodically by comparison at several temperatures with a certified mercury

thermometer. A Fisher Accumet 150 portable pH meter with plastic body combination electrode and a Fisher Model 107 pH meter were used for pH determinations. The former was found to be less satisfactory because of its lower reliability at low temperatures. Although all tests were carried out on site, only the temperatures were determined in situ.

RESULTS

REGIONAL BREAKDOWN

Results are presented under the major headings and following the same order as described above. The territory was divided into six regions since significant regional differences in water quality, culture techniques and marketing patterns were found. These regions are:

1- Northwest Quebec
2- St.Lawrence Lowlands
3- Eastern Townships
4- Beauce
5- Northeast Quebec
6- Gaspe Peninsula

The major drainage basins of Quebec are illustrated in Figure 3 and the limits of the regions are illustrated in Figures 4 to 9.

QUESTIONNAIRE RESPONSES

Heading and identification

The identification section of the questionnaire consisted of the following questions:

I. Name of operation:

Post Office address:
Telephone number:
Location:
County:
Township:
Lot number:
Watershed:
Type of licence:

II. Owners

Name (s) and address (es):
Telephone number (s):

III. Years in operation:

IV. Number of employees, both full-time and part-time, including the manager:

The regional distribution of licenced hatcheries is listed in Table 4, with a breakdown by category and an indication of those which were sampled. Figures 5 to 9 show the approximate location of governmental and private hatcheries within each region, and indicate those which were visited in the course of this survey. Table 5 identifies the hydrographic area (Figure 3) and individual river basin to which each hatchery surveyed belongs. It should be noted that all but three of the hatcheries drain to the St.Lawrence. Two of those which do not, flow to James Bay and one to the Connecticut River.

For the past few years, there has been a dramatic increase in the number of fish culture permits issued (Figure 10). The leveling off appearing between 1977 and 1978 is partly due to changes introduced in 1978, involving new category definitions. The present system allows for the following categories of licences:

Category I: Commercial establishments involved in the breeding and rearing of fish for the following purposes: reproduction, extraction and fertilization of fish eggs, incubation of fish eggs, stocking of live fish, production of food or recreational fishing in an authorized fish pond.

Category II: Non-commercial establishments involved in the incubation of fish eggs and rearing of fish for personal, recreational or restocking purposes, but where there is no resultant sale of fish.

Commercial fish ponds: Establishments where angling is permitted throughout the year, provided that: the operator has been granted a Category I permit; the pond be situated on private property and adequately enclosed on all sides to prevent the escape of any fish; the pond have a surface area under 10 hectares (25 acres); the pond be stocked with and contain only those salmonid species permitted for rearing.

A fourth category, "Fishing ponds", comprises installations in which no breeding or incubating is carried out and which depend entirely upon hatcheries as suppliers for their stock. Figure 11 shows the breakdown of permits granted in 1978 within the categories described above. The reader is referred to Appendix B for further details related to the regulations.

Prior to 1978, there were three categories of permits. Category I covered all commercial aspects of the breeding and rearing of fish; the new Category I is roughly equivalent. Category II applied to commercial establishments breeding and rearing rainbow trout for stocking or sale as food. Category III was equivalent to the present Category - II; it included non-commercial establishments involved in incubating eggs and rearing fish for the purpose of stocking.

The total number of licences issued in 1978 was the same as in 1977 (Figure 10). In fact, 54 new licences were issued in 1978 (Figure 11), representing a 26% increase in the number of commercial licences (all categories except Category II) over the previous year. Conversely, 41 out of the 54 licences which were not renewed in 1978 were non-commercial permits. It should be mentioned that in 1977, 16 Category III licences applied to fishing ponds operated by outfitters and thus were considered as commercial operations. Figure 11 illustrates how those who did renew their licences in 1978 fit into the new categories. In our opinion, the number of Category II licences issued in 1978

does not reflect the actual number of non-commercial rearing ponds. In fact, the number of private ponds in Quebec has been stated to be in the order of 5,000 and increasing (Boulanger et al. 1977). It is most likely that many more private ponds have been seeded at some time than would appear from the Category II licence figure.

Table 6 shows the age of the private hatcheries surveyed. These hatcheries were selected largely on the basis of the 1977 licenced hatcheries list. Newly licenced (1978) hatcheries were also sampled, but in a smaller proportion. Therefore, the number of hatcheries in the 1-2 year class is underrepresented and the mean and median ages are in fact lower than calculated.

The number of employees, hobby-owners and people deriving a substantial portion of their income from the hatcheries surveyed is indicated in Table 7. It is felt by the authors that the figures presented for full-time and part-time employment are fairly representative. In fact, the selection of the hatcheries aimed principally at commercial installations established for two years or more. On the other hand, figures for hobby-owners and self-employed hatchery operators may be disproportionately low.

For the present purposes, hobby-owners are defined as individuals practising fish culture on an amateur basis, who do not depend upon fish culture to any extent as a source of income. Annual sales within this category, when they occur, generally amount to less than two thousand dollars. The "self-employed" category includes individuals who derive a substantial portion of their annual income from the enterprise, generally over two thousand dollars, but for whom fish culture is not the sole source of revenue. As would be expected, a certain amount of progression occurs over the years, with operations passing from one category to another.

The employment figures presented in Table 7 apply only to the hatcheries surveyed. From these figures, we can extrapolate to get an overall estimate of employment provided by fish culture installations in Quebec in 1978. Out of 257 fish culture installations, 122 were sampled (Figure 11). A total of 115 had commercial licences (Category I, Category I and Pond fishing), three had non-commercial licences (Category II) including two research installations each hiring a full-time manager, and four were not licenced. The remaining 135 installations include 87 non-commercial ponds (Category II) which are not suspected to create any regular employment as they are probably all operated by hobby owners. Assuming that the same proportions as apply to our sample hold true for the 48 commercial hatcheries excluded from the sample, we should add to the figures of Table 7, 17 hobby-owners, 29 self-employed individuals, 14 part-time employees and 12 full-time employees. This would bring the totals for all fish culture installations within Quebec to 149 hobby-owners, 103 self-employed individuals, 51 part-time employees and 43 full-time employees.

SECTION I: Description of stocks reared and of production

The first section of the questionnaire included the following questions (see Appendix D for more details):

1. Which species do you raise? Please indicate the number you have at present in each category.

2. What are the sources of this year's stock and what are the quantities from each source?

3. How did you dispose of your production in 1977? Please specify the number and the category (A-F) for each age class.

4. What were your estimated losses per species and age class in 1977?

5. If you produce your own eggs, how many brood fish do you have of each sex and age class?

6. What was your total production per species in 1977?

It was initially hoped that compilation of an inventory of the fish held within private hatcheries would be possible. It soon became apparent, however, that most operators could not give accurate estimates of their fish on hand, nor could they supply reliable figures for any specific date in the past. It was therefore not possible to prepare an accurate quantitative inventory of the fish raised in Quebec for any particular date. Table 8 provides a list of the species cultured and the number of installations raising them. While speckled trout is still the most popular, rainbow trout has been steadily growing in popularity. In the past, Atlantic salmon, ouananiche, brown trout and splake have all been raised by private hatcheries. The MLCPQ has raised all of these species as well as Danube salmon and muskellunge, yellow perch and black bass (Appendix A and Table 1 list the scientific and common names of the species reared).

Question I.2 attempted to establish the origin of the stocks in the hatcheries. While there is a considerable trade between hatcheries, this fact did not emerge from the responses to the extent

anticipated.[1] The reasons for this are not clear; it is suspected that the operators did not consider those fish to have been part of their production as fish purchased from other hatcheries are generally re-sold immediately. Purchases and sales of eggs on the other hand, were easily established and are reported in Table 9. It is of interest to note that 33% of the hatchery operators buy their speckled trout eggs from more than one source, with the rationale that this reduces their chances of loss by disease or inferior stock. On the other hand, 56% of the hatcheries which maintain brood stocks are entirely self-sufficient in terms of their egg requirements. In this way, they attempt to avoid problems related to introduction of disease or inferior stock. Few operators seem concerned with inbreeding depression; most individuals questioned about this aspect seemed unaware of the hazards it represents. The fact that most fish culture installations are relatively young undoubtedly accounts for the lack of awareness of problems in this context.

In 1978, there were but one or two hatcheries self-sufficient in spring rainbow trout, but this number is expected to increase.

In Table 9, the figures listed under "Purchased from MLCPQ hatcheries" refer to eggs sold by the Government of Quebec. The total number of eggs incubated by private hatcheries equals the number of eggs purchased from public hatcheries (last column) plus the number produced from brood stocks of private hatcheries (second column to the last). This is not so within regions as sales sometimes occur between regions. The numbers of eggs purchased from private hatcheries are included in the figures under "Produced from broodstock of private hatcheries".

Table 10 shows the sales of cultured fish reported for 1977. These figures should be interpreted with some caution. In most cases, the only information obtained was an estimate made by the operator. Some figures reported by one hatchery were not considered realistic and therefore were correspondingly adjusted. It is also believed that some hatchery operators may have included 1978 sales in their total for 1977, as responses to that question were given for hatcheries that were not licenced in 1977. In any case, the quantities involved in this instance are negligible. Unfortunately, it was not possible to figure out the quantities of fish that used to be sold for stocking private or leased waters as respondents could not remember that information.

1 The MLCPQ determined that in 1977, inter-hatchery sales of fish represented 32% of the total number of fish sold. However, 85% of those fish sold between hatcheries were under 5 cm. Inter-hatchery sales of fish larger than 5 cm represented only 4.8% of the total sales.

In question 1.4, operators were asked to assess their losses by species and age class for 1977. The results, summarized in Table 11 and Figure 12, show that mortality is heaviest amongst alevins with losses frequently exceeding 75%. At that stage, losses are severe for speckled trout, less so for spring rainbow and most severe for fall rainbow. Fall rainbow alevins show the greatest frequency of occurrence of losses exceeding 75%. They also have more trouble as fingerlings.

Cold winter incubating temperatures, particularly when the fry begin feeding, high water temperatures during the summer and susceptibility to disease may all account for the heavy losses reported for speckled trout. Cold temperatures may also account for fall rainbow losses. All fall rainbow trout reared in Quebec are imported from California where they are incubated at relatively high temperatures (8 to 10 C). The acclimatization (long-term) and acclimation (short-term) stresses coupled with long transit periods may account for the considerable losses reported. On the other hand, spring rainbow trout is spawned in Quebec and thus is not subjected to such stresses. The lower losses reported for that variety may be a reflection of this.

The figures given in the case of yearlings and older fish lose some of their significance because of the smaller number of respondents. Nevertheless, speckled trout still seems subject to greater losses and this is most probably due to the high water temperatures experienced during the summer.

The number of eggs incubated by private hatcheries has been rising steadily for the last 8 years (Figure 13). Table 12 shows the number of broodfish kept for this specific purpose. The apparent discrepancy in total numbers of one- and two-year speckled trout, in which the younger fish reported are less numerous, is accounted for by the fact that speckled trout are not selected for broodstock until they are two years old. Similarly, this would explain the difference in numbers of 2 year old and 3 year old spring rainbow as this is a later maturing fish. Therefore, this discrepancy between the numbers of younger and older fish identified as brood stock cannot be taken to represent a reduction in the number of future brood trout. The number of speckled trout available for brood stock would seem to indicate that the private sector has the capacity to supply its own needs. However, this is not the case as most hatcheries limit their production to fill their own requirements only.

SECTION II: Operational data: causes of loss, treatment of diseases and feeding.

1. What have been the principal causes of mortality in your installation?

2. Do you use any chemicals or drugs for the prevention or treatment of disease?

3. Have you ever had your fish examined by an expert in fish diseases? If so why, and what were the results?

4. What feed(s) do you use? Are there specific reasons for your choice?

5. How much do you use of each brand per year?

While it is felt that hatchery operators assessed the production loss and its causes to the best of their ability (Table 13), the situation is somewhat more complex than appears in Table 13. For instance, fungus and bacterial gill disease are general symptoms of stress-related diseases and cannot be considered the sole causes for the losses attributed to them.

Chemical products and numbers of establishments using them for disease control, disinfection and control of algae are listed in Table 14. Only those 84 hatchery operators who were personally interviewed were asked question II. 2. Nevertheless, Table 14 gives an accurate picture. The hatchery operators who were not questioned on that matter ran newer installations and it is believed their use of chemicals would not be significant. Of those asked who did not respond, it is believed that either they did not use any chemicals or they did not feel they used enough to warrant mention. Many if not most operators are known to use household disinfectant bleaches (sodium hypochlorite, Javex, Chlorox), but none reported using these products, possibly because they were not considered fish-related chemicals. Only five respondents expressly stated they did not employ any chemicals.

An attempt was also made to ascertain whether the chemicals were properly used. Questionnaire and interview results indicate that most operators use the "safer" products such as salt and malachite green following instructions supplied either by the MLCPQ or by other private hatchery operators. After a period, these chemicals are often used without precaution. The more dangerous chemicals were either not used at all or utilized with extreme caution in low dosages with the result that they were often ineffective.

Question II.3 brought to light the interesting observation that a surprisingly small number of hatchery operators have sought expert help in identifying and controling the disease problems they encountered. In fact, the positive answers were so few as to preclude the tabulation of results. It is obvious, however, from comments volunteered in a subsequent section, that hatchery operators see a real and urgent need for the establishment of a mechanism which would provide them with access to a diagnostic service and to advice on disease prevention and control.

Table 15 lists the extent of usage of various prepared feed brands and natural fish foods used in Quebec. Many operators expressed concern over the quality of the prepared feeds available. Problems attributed to feeds range from claims of batches with toxic effects to batches deteriorated by excessively long warehousing. A number complained of high dust levels in the feed, which they felt contributed to poor conversions and to gill problems. Still others questioned the adequacy of formulation of the feeds as they relate to Quebec's climate. Although many expressed preferences for a particular brand, there was no brand without its proponent or opponent. The wide use of one particular brand should not be interpreted as a statement of greater confidence in this brand by hatchery operators, although its quality is not in question here; rather it seems to relate to the fact that its distribution is much better organized and that it offers a floating ration. The large number of pisciculturists using liver or more than one food item is related to the lack of confidence which many of them seem to have in prepared diets.

SECTION III: Water supply, treatment and utilization

1. What are the sources of water available to you? For each different source, please indicate: the temperature range, the maximum and minimum flow of water used for culture and the maximum and minimum flow of water available.

2. Have you ever had your water tested? If so, what was it tested for and what were the results? Please also indicate who performed the test.

3. Do you recycle any water? If so, please describe your system.

4. Do you heat or cool your water? If so, how?

5. Do you aerate or de-gas your water? If so, how?

6. Do you filter your incoming water? If so, please describe your system.

7. Where is your water discharged? Do you treat the discharged water?

8. How many pumps do you have and what is their capacity?

9. Do you possess a back-up system in case of break-down?

10. What types of upstream activities are there above your installation?

Table 16 shows the sources of water used by private fish hatcheries in the province. Springs are the most commonly used source and lakes supply the largest volumes. Most respondents considered high summer water temperatures as the most important limiting factor, with quantity and quality secondary considerations. The wide temperature fluctuations (Table 16) of waters which should be more or less stable, are due to their frequently being piped or channelled to the hatcheries over long distances without insulation. While it is not really evident from the table, some areas are more apt to have certain types of water sources in abundance because of their geological characteristics. For example, the chance of locating a good well is better in the St.Lawrence Lowlands than in the Laurentians. Conversely, satisfactory surface water is more abundant in the Laurentians than in the St.Lawrence Lowlands.

Responses to Question III.2 revealed that operators lacked knowledge relating to the quality of their water supply. A few respondents had had tests done by public health laboratories on well and spring water, particularly in cases where this water was at one time considered as potentially potable water. A fair number of operators had obtained commercial water testing kits (oxygen, carbon dioxide, alkalinity, pH, temperature). However, none was met who put those kits to efficient use. Moreover, it soon became apparent that there exists a general lack of understanding of the significance of the various parameters.

Several operators reported that their water had been sampled and tested at some point by government agencies, but that the results of the analysis had not been communicated to them.

As previously mentioned, water tests were carried out as an integral part of this survey. Results follow in a later section.

The number of hatcheries which recirculate their water is shown in Table 17. Recirculation generally involves pumping effluent water to a header where it is mixed with incoming fresh water. Those who recirculate do so in order to reduce the costs of heating incubation water and to compensate for a lack of flow in midsummer or midwinter. Lately, a few hatcheries have begun to exploit their water sources more extensively by oxygenating and recirculating up to 90% of their effluent water. In Region I, a significantly lower percentage of effluent water is recirculated; this reflects the more abundant types of water supplies in that region.

The number of installations heating incoming water is shown in Table 18. As we mentioned above, many of those who recirculate their water do so in order to reduce the cost of heating water to satisfactory temperatures for incubation during winter months. Methods used include passive induction and electric, propane, oil and wood water heaters. Operators were also asked whether they cooled their water. Although many had considered the possibility, none did so, as the operation was found to be uneconomical. Also, two operators outlined plans to use heat exchangers in deep wells but neither of those schemes has yet been realized.

Aeration methods and the extent to which they are utilized are listed in Table 19. The various devices reported are described below. Pumps are the most frequently used device. They combine the principles of falls with that of entrainment as water is injected into the containers under considerable pressure. They are often used to improve the distribution of oxygenated water in the rearing container. Riffles and falls are the next most commonly used method reported. Water is allowed to drop before entering a fish-rearing container. This method is often improved with the use of perforated trays, splashboards or stairs. Surface agitation is conducted at some sites in larger tanks and ponds.

This involves breaking up the water surface with a propeller, paddle or brush. However, only the propeller was encountered within the province. Another method, the venturi is a device used to induce air into a body of water by means of atmospheric pressure. It involves the pumping of water through a flared constriction and entrainment of air on the low pressure side. In some cases, the air pumped into a body of water is reduced into small bubbles by means of a diffusor. Perforated pipes, plastic and rubber tubes, carborundum stones and many new materials are used for this purpose. Most operators (86.5%) use pumps or falls to aerate water. However, these simple methods are not used to their full potential. The main reasons for this seem to be a lack of understanding of the benefits to be derived, and a fear of relying on mechanical methods. A few exceptional situations were seen where the dissolved oxygen requirements of the fish were from 5 to 10 times higher than the oxygen supplied by the incoming waters. In four installations, aeration served as a security against supersaturation in ground waters, heated, pumped or pressurized water supplies.

Questions III.6 and III.7 were included to determine the extent to which filtration and other methods of water treatment are used. Several installations reported screening the incoming water by means of window screens, perforated plates or similar devices. In some of the cases where water was recirculated, commercial sand filters or fiberglass wool were used. Sedimentation basins are used in a few instances to treat the effluent, and in one case, in a semi-closed recirculating system. While several reported using sedimentation basins, it is worth noting that many of these could not operate at satisfactory levels of efficiency because of turbulence due to unacceptably high rates of flow i.e. velocities greater than 0.033 m/s and less than the recommended 15-minute minimum retention time. As the MEQ now insists that all new fish rearing installations have settling ponds, their use is bound to increase.

A number of operators consider the softness and low buffering capacity of their water supply to be a limiting factor. They attempt to remedy the situation by passing the water through crushed-limestone beds. In one instance anhydrous lime was added to a semi-closed system. Single instances were also seen involving the use of in-line polyester filters, cartridge filters, and Mg-Zeolite filters (for removal of dissolved iron); these were found in hatcheries recirculating water for incubation. One such hatchery, dependent upon a municipal water supply, dechlorinates its incoming water by passage through an open basin.

It is felt by the authors that the whole area of water treatment is one which warrants more attention than it has received in the past. Although water chemistry varies greatly from one region of Quebec to another, steps can certainly be taken to make waters more favourable for fish culture. One of these steps could be a well-planned information program designed to provide information to fish culturists as to the basic water requirements of their fish.

Table 20 summarizes the responses given to Question III.8. Additional information is given in Table 21 in which the figures under function columns refer to the percentage of installations in a particular region which use pumps for the corresponding function. These data do not include those pumps which are used for general purposes such as water transfer and pond drainage. While 64% of all hatcheries surveyed use pumps, the great majority of these are sump pumps used for aeration, or well pumps. The discrepancy between regions II, III and IV where over 80% of installations use pumps, and regions I and VI where less than 40% do so, may seem surprising. The reason for this discrepancy relates to differences in terrain and in the nature of the water supplies available in each region. Regions I and VI are relatively less dependent upon pumped well water than the other regions (Table 16 and 21).

Dependence on pumps requires many operators to have back-up or emergency systems. These include duplication, alarms for water level or pressure changes and power failure, gasoline pumps and stand-by generators. Duplication was impossible to evaluate. However, figures for alarms, pumps and generators are listed in Table 21.

Hatchery operators were also asked to identify the actual and potential types of upstream activities which could have an effect on their installations (Table 22). Nine respondents could think of no upstream activities which could affect their hatcheries. Their feeling of security was either derived from a belief that springs and wells could not be affected by nearby human activities or from the fact that they owned all the surrounding lands. Other operators were generally concerned with forestry, agriculture, residential construction or some combination of these. Some of the sites we visited were already being threatened by agricultural runoffs or the indiscriminate use of chemicals (i.e. algaecides, herbicides, insecticides).

Surface waters are the most hazardous source of water. There are reports of total fish kills as a result of the negligent use of herbicides by upstream parties. Several operators were forced to abandon some surface water supplies at certain times of the year, not only under conditions of heavy rainfall when pollutants were washed into their stream but also when decreasing water levels concentrated the pollutants. Abnormally high nutrient levels (NO_3 particularly) were observed in surface waters and wells in the vicinity of intensive agriculture. Some people also mentioned that springs were drying up, water level in wells was lowering and surface water was adversely affected following deforestation.

SECTION IV: Technical description of physical plant

In this section, operators were asked to describe their equipment. The information obtained from the questionnaire and from visits carried out by the survey team is presented in Table 23. Notes and measurements taken by the survey team during the course of the study establish that the following methods of construction and ranges in size prevail within Quebec:

Troughs: Rectangular containers ranging in length from 2 to 5 m and in width from 25 to 50 cm. They are supplied with 10 to 30 liters per minute. Troughs are usually made of wood. Fiberglass-resin is also used and wood troughs are often coated with fiberglass and polyester resin or plastic sheeting. They are used for the incubation and hatching of eggs as well as the rearing of alevins.

Tanks: Freestanding rectangular containers larger than troughs but smaller than raceways. Flows are sufficient to provide a change of water in 30 to 60 minutes. They are often made of concrete, but wood is common and stainless steel (dairy bulk tanks) is popular. In one installation, fiberglass-resin tanks were used. Tanks are multiple purpose facilities.

Raceways: Rectangular basins with sizes in the proportions 30 X 3 X 1. They are 15 m or more in length and require an hourly exchange rate or better. Raceways are made either of concrete or gravel-lined earth. They are used for the rearing of large fingerlings, yearlings and older fish.

Circular ponds: Cylindrical containers, often with conical or saucer shaped bottoms, with a central drain. They range from 3 to 20 m in diameter and from 1/3 to 2 m in depth. The water supplied is minimal, but it usually is injected at high velocities. They are excavated in the ground, lined with gravel, and often have concrete walls. Circular ponds are popular for fry and fingerlings as they supply the velocity and space needed with a minimum of water.

Ponds: Natural or artificial enclosures of various shape, size and water supply. They usually are less than 50 m in length and width. By definition of the Quebec Fishery Regulations, they must be less than 10 hectares in surface area. In certain terrains, ponds are lined with vinyl sheeting. One operator reported having lined a pond with concrete and another with asphalt. Ponds are very popular for fingerlings and larger fish.

Vertical flow incubator: These are in all cases commercial fish egg incubators. It should be noted that jar incubators were used in government's installations but not in private hatcheries.

Most private hatcheries have followed the instructions given in "Les bassins de pisciculture" (Paulhus 1972), which describes construction planning of fish-culture installations, including the various types of pools used in fish-culture, their respective advantages, and drainage devices.

Supplementary equipment varies in quantity, nature and sophistication depending on the size and purpose of installations. Pay fishing installations generally have but a few pails, fishing rods and one or two seines along with a dip net. They also have reception buildings which vary a great deal in size from place to place. Most installations in which eggs are incubated have a building which serves specifically as an incubation site; however, some operators conduct the hatching in the basement of their homes. Five or six of the larger hatcheries have automatic feeders, some homemade. Several operators use tractors and trucks. Also found in many hatcheries are test kits for water analysis, predominantly dissolved oxygen and pH.

SECTION V: Assessment of technical and economic efficiency of operation, and desiderata.

1- With your present equipment, do you feel you are exploiting the full potential of your installation?

2- Do you presently have all the information needed to calculate your production costs and profit margin?

3- Do you envisage changes in your market, and consequently in your type of production, following the new regulations with respect to declubbing and zone restrictions?

4- If you were offered technical and financial aid, what improvements would you make to your hatchery?

Some of these questions were included at the request of the MAQ as a means for them to assess the attitudes of hatchery owners concerning recent changes in legislation and their implications on the future of the fish culture industry in Quebec. As mentioned previously, this entire section was omitted in the shorter version of the questionnaire used for telephone and mail survey. Therefore results which follow represent responses obtained from the 84 hatchery operators who were personally interviewed. Not unexpectedly, some individuals preferred not to answer some of the questions; others did not feel qualified to comment.

Responses to question V.1, in which managers were asked to evaluate the efficiency of their operation, are summarized in Table 24. The majority indicated they felt there was considerable room for improvement. Numerous reasons were given and these are incorporated throughout the present report.

The survey team also attempted to determine whether financial records were kept in sufficient detail to make possible the calculation of production costs and profit margins (Table 25). Answers show that a surprisingly low proportion of the hatchery operators do so (34%). Regions I and VI show the highest proportions, 71% and 75% respectively. Considering that only 35 interviewees responded to that question, the actual proportion of operators keeping adequate records may be lower than the above figures indicate.

A specific attempt was made to elicit free comments on the impact of the recent changes in legislation upon the orientation of production and markets. The frequency distributions of responses are shown in Table 26 (zone restrictions) and Table 27 (declubbing). The results should not be considered to represent a poll; rather, they display the range of opinions expressed by fish farmers.

The majority of comments can be interpreted as being motivated more by concern and uncertainty for the future than as statements of real, immediately apparent economic impact. As the changes in regulations were implemented during 1978, it is not to be expected that the full impact can be realistically assessed from comments obtained from trout farmers during the first year of application.

All welcomed the legalization of pond fishing for speckled trout, but several operators voiced complaints concerning the need for tagging each individual fish caught. There are a few operators who feel they can demonstrate actual financial losses for which they are not being compensated. A number of those who have expressed concern, feel the recent steps, if handled correctly, could be beneficial to the industry in the long run. Three operators who privately expected an immediate increase in sales due to the abolition of private clubs, responded that the effects were not yet known.

The final question in this section attempted to define what improvements would be made if technical and financial assistance were available. Most respondents placed the emphasis on monetary aid. This is not to suggest technical help was not wanted; the suggestions made (excavation, draining, etc...) represented problems whose nature seemed to them to be more financial than technical, and that set the tone for the responses. The major areas of interest were the drilling of wells and the construction of ponds and lakes. Drainage was often mentioned as a means of tapping springs. Others wanted assistance in constructing buildings such as incubators, toilets and offices. A few said that grants to help them purchase neighbouring land would provide them with more water or control of the source of their present supply. The purchase of major equipment such as generators, aerators and water testing equipment were all mentioned. Others expressed interest in the consolidation of existing debts.

A large number of operators did not respond because they felt they would not be eligible for assistance. Still others felt government assistance would compromise their independence and hence wanted to have nothing to do with it. More information concerning fish culturists' expectancies is provided in the following section.

SECTION VI: Comments and suggestions proposed by operators:

1. What are the most important problems presently facing fish farmers in Quebec?

2. What steps could be taken to help remedy those problems?

3. What governmental actions and services do you feel could be most helpful to the industry?

The survey team asked 84 operators to comment on the problems of the fish culture industry in Quebec. Thirty-eight operators did not respond. They felt they were not qualified to comment because either they had not been in the business long enough or they were not large enough producers to be aware of those problems. They also felt that problems they encountered were more or less personal and had nothing to do with the concerns of the industry as a whole.

Forty-six operators responded to Section VI. Comments can be divided into four areas of concern: scientific and technical assistance, marketing, financial assistance and governmental policies.

Thirty-four operators commented on scientific and technical assistance. Twenty-three mentioned there should be a service similar to that offered to farmers through the present system of district agronomists, that is technicians capable of offering direct and immediate assistance. This service should also be available to those interested in site evaluation. Seven operators responded that there is a need for an educational service whose aim would be to raise the competence of the fish farmers themselves. Twelve respondents expressed concerns over feed. Some felt that all feed brought into Quebec should be inspected and analyzed. Others felt that manufactures should be subject to a greater degree of quality control; prices are felt to be out of line by many. It was also suggested that research be conducted in order to establish the nutritional requirements of salmonids in Quebec's climate. Disease was a concern to six who felt that a diagnostic and treatment service is required. Some suggested that the parties responsible allow those private enterprises that wish to, to participate in the certification program (Anonymous 1977b). Lastly in this area, it was mentioned that a breeding program should be established in order to improve the fitness of speckled trout to intensive culture.

The next major area of concern was that of marketing. Twenty-two owners commented on this problem. Six of them felt that the market fluctuates too much so that they cannot forecast future sales. This is especially so in the case of hatcheries supplying fry for stocking, a market which in many areas suffers from excessive competition as well as a drop in sales due to the abolition of private clubs on public lands within the province. Four operators expressed the opinion that foreign trout, because of their lower cost, should not be imported as importation keeps local enterprises from selling their product at the price they require. Five others thought that a lack of confidence together with a lack of planning prevent the production potential of the industry from being realized. A few respondents stated that the MAPAQ policy of assistance to farmers did not take into account its effects on the regional markets of already established enterprises. Many expressed the opinion that they could not simultaneously be producers and salesmen, and felt there should be an agency to help them market their product. Some suggested the assistance could take the form of an advertising program. It should be mentioned that a recent grant from the Government of Quebec has allowed "La Coopérative québécoise des Pisciculteurs" to start a full time office; it is hoped that this will reply to many of the concerns expressed by the hatchery operators in this context.

Financing was of major concern to some twenty respondents. Banks and other financial institutions regard fish culture as a high risk venture and are very reluctant to invest in it. However, most operators feel that there is a potential and a need for commercial fish production and that some sort of financing should be available to them. As to what form this assistance should take, most people could not answer; many felt that the MAPAQ's programs are a good start. It was also stated that guaranteed and low interest loans combined with tax credits to those investing in fish culture projects would be helpful.

The last area of discussion was government policies. Six owners responded that government agencies were directly responsible for retarding the industry. Their complaints expressed concern over the lack of coordination between governments or their various departments.

BIOLIGICAL SAMPLES

Biological samples were taken for laboratory examination. The majority of those which were subjected to bacteriological examination revealed myxobacterial infections, particularly columnaris (Chondrococcus columnaris) which was found in both

rainbow and speckled trout. Aeromonas hydrophyla and Aeromonas sobria were also identified. Most disconcerting was one confirmed identification of furunculosis (Aeromonas salmonicida). We believe this to be the first report of the disease in a private hatchery in Quebec. Two samples were sent to the Fish Health Unit in Halifax for viral examination. Both lots were determined to be carriers of infectious pancreatic necrosis.

WATER TESTS

Some two thousand measurements including 12 parameters were made on water samples from 84 sites. The location of these sites is shown in Figures 5 to 9. Both the incoming water and the discharged water were sampled. Sources of water supply included springs, wells, brooks and lakes. Results are summarized in Figures 14 to 25. Few installations were found to use the water table as a water supply and therefore measurements made on samples from the water table are not included in this report.

Temperature

Temperature observations are summarized in Figure 14. The mean temperature observed in springs (10°C) and wells (9°C) was lower than that observed in brooks (14°C) and lakes (15°C). Incidentally, the water from several springs and wells is heated during the summer before it is used. This accounts for some of the discrepancies in the data on spring and well temperatures, between the ranges measured by the survey team (heated water) and those reported by the managers (before heating).

Surprisingly, there are no marked regional differences in mean temperature of springs, wells and brooks. However, regional differences in lake temperature are pronounced, with regions I and V having the lowest records. High temperatures were recorded mainly in ponds and pond discharges. However, it is likely that some of those ponds were thermally stratified. Nevertheless, where surface temperatures reached lethal levels, fish stocks were maintained at low densities.

Wide ranges and large deviations show that most water supplies were influenced by ambient air temperature. Surprisingly, this is also the case with many springs and wells. The wide temperature fluctuations of these waters, which should be more stable, may be due to their frequently being piped or channelled to the hatcheries over long distances without insulation.

Observations should be interpreted with caution because site visits were spread over six months and water temperature was dependent upon air temperature. So, the range measured by the survey team should be considered as a minimum. Notice also that the maximum temperature of springs and wells reported by respondents is frequently less than that measured by the survey team. This suggests that some managers are not fully aware of the prevailing temperatures in their water supply or that some managers reported the temperature range of water before heating whereas the survey team measured the temperature range after heating.

pH

Extreme values were found in lakes and ponds (Figure 15). Those of region I are most acidic whereas those of regions III and VI are most alkaline. The underlying bedrock of region I is composed mainly of granitic gneiss. High pH's in some lakes and ponds and in discharged water are likely the result of photosynthesis or crowding.

The mean pH of springs (7.2) and brooks (7.3) differ from that of wells, with well water being most alkaline (7.6). However, there are large regional fluctuations, particularly with well water. Comparing the regions, the mean pH of water is higher in region II (7.6) and region IV (7.6) than in other regions. Based on the range in pH of springs in region VI, that region likely is comparable to region II and region IV.

Dissolved oxygen

Dissolved oxygen levels are shown in Figure 16. Many sources were found to be below satisfactory minimal levels (Boulanger 1978). Wells were particularly deficient. In some instances, levels dropped below 10% saturation. The mean level throughout the regions was 65%. Several respondents reported cases of supersaturation in wells, particularly in winter and spring, but no such instances were observed in the course of the survey.

In brooks and lakes, the mean percentage of saturation (90%) is higher than that of springs (80%). However, levels never dropped below 35% in springs whereas brook and lake levels dropped as low as 25%. Frequently, lakes and ponds and discharged water were supersaturated due to photosynthesis in basins receiving a heavy load of nutrients or having a slow turnover rate. Under such conditions, low dissolved oxygen levels are to be expected at night. Low levels also occurred in water discharged from crowded basins.

Carbon dioxide

Carbon dioxide levels (Figure 17) were highest in sub-surface waters, namely springs and wells. Higher levels are to be expected in growndwaters:

water becomes enriched with carbon dioxide from plant and microbial decomposition as it passes through the soil. When pressure is released, the carbon dioxide level drops back to a lower level. Notice for instance the fairly low concentrations in discharged water.

High levels were also observed where samples were collected early in the morning or on cloudy days, from basins in which plants were abundant. Fish respiration can also increase the carbon dioxide level of crowded basins in water having a low buffering capacity as in region I and region V.

Ammonia nitrogen

Ammonia nitrogen concentrations were low in most water supplies (Figure 18), generally less than 200 µg L^{-1}. However, several sites had higher concentrations suggesting organic contamination. In many instances, the source of contamination was obvious: manure pile, cesspool etc. Highest concentrations were found in discharged water, which is not surprising since ammonia is a by-product of fish metabolism. Nowhere, however, was the ammonia concentration high enough to be considered as threatening.

Nitrite nitrogen

Nitrite nitrogen (NO_2-N) concentrations (Figure 19) were exceedingly low (10 µg L^{-1}) in incoming water. Where water was recycled, concentrations rose up to 160 µg L^{-1} in discharged water. This is close to median lethal concentrations reported for rainbow trout. However, the high concentration of chloride (20 mg L^{-1}) in those waters might have exerted a protective effect.

Nitrate nitrogen

Nitrate nitrogen (NO_3-N) concentrations (Figure 20) range from 0 to 6 mg L^{-1}. Springs and wells average higher concentrations than brooks and lakes, probably due to fixation by plants. Similarly, regional differences occur, with nitrate being more abundant in regions II, III and IV than in the more northernly regions I and V. Regions II, III and IV lie in the densely populated productive agricultural plain of the St. Lawrence. That, together with the characteristics of soil and underlying rock formations can account for such regional variations.

Chloride

Chloride ion concentrations (Figure 21) were fairly high, compared to the average concentration in natural fresh waters. Wells of region II and region V contained up to 340 mg L^{-1} in some locations. The presence of marine sediments in those drainage basins, located in the ancient Champlain Sea basin, is likely responsible for such high concentrations.

Phosphate (PO_4)

The method used to measure phosphate concentrations yielded little information. Available data are summarized in Figure 22.

Iron

Dissolved iron concentrations were low (0.2 mg L^{-1}) in most installations, particularly where the pH was high and the dissolved oxygen near saturation (Figure 23). In anoxic water, ferric and ferrous hydroxide precipitates and ferric hydroxide flocs produced by ferruginous bacteria, both caused gill problems and in some instances severe mortalities among fry and alevins. The use of aerators and settling ponds turned out to be helpful in some installations.

Alkalinity and hardness

Data on alkalinity and hardness are shown in Figure 24 and Figure 25. Both parameters follow a similar pattern of variation. Groundwater tends to be either softer or more alkaline than surface water. In region I and region V, where water has a low pH and flows over granitic gneiss rock formations, water is soft and much less alkaline than in other regions.

Samples were taken periodically at some sites. It turns out that the calcium carbonate content of water is highly variable in wells. At one site, it increased from 60 to 160 mg L^{-1}. This could be related to precipitation and seasonal fluctuations of the water table level. Hence, the concentration of other parameters is likely to fluctuate in wells.

DISCUSSION AND CONCLUSIONS

THE MARKETS

Private fishing clubs

From its beginnings till the early 1970's, the development of the Quebec piscicultural industry has been closely linked to that of private fishing clubs (Asselin et al. 1976, Léger 1977). The Quebec government followed a policy of leasing fishing rights on crownlands as a mean to preserve and manage the natural resources, the rationale being that it is in the interest of lease holders to properly manage the fauna within their territory. The membership and the number of private fishing clubs had grown rapidly until 1967 (Figure 26). Although statistics are not available for that period, it can be assumed that sales of fish increased accordingly, since the number of eggs incubated increased over the end of that period (Figure 13).

By the end of the 1960's, the number of fishing clubs began to decrease. With this decline, there was a leveling or perhaps a slight decrease in the demand for fish. By 1976, clubs had stopped buying large quantities of fish. They stocked their territories with few larger fish so as to make sure they would benefit from their investment. The termination of leases to private clubs came into effect in 1977, following several years of debate. While exclusive rights were abolished, private clubs were allowed to maintain their camps. With the disappearance of most clubs in 1978, many pisciculturists lost a major market for their products (Figure 27). Some private clubs located in remote areas keep on stocking waters but their demand for fish is not significant.

The provincial government took concrete measures to support enterprises which had sold fish to private clubs in the past. However, it was pointed out that some of those enterprises had sold fish produced by other establishments which are not themselves being directly compensated under the present program. Also, larger and fewer fish are being sold now than used to be sold to private clubs, and without discounts. Therefore, the sales benefit fewer pisciculturists and the money is not distributed in the same pattern as before. Hence, several pisciculturists have complained about compensatory purchases.

Zones d'exploitation contrôlée (ZEC's)

ZEC's are being established throughout the Province; they are responsible for the stocking of fish in their territories. Sales of fish to ZEC's for the purpose of stocking could make up for lost sales to private clubs. Whether that market will grow depends on the success of those local organizations. However, many pisciculturists fear that ZEC's will eventually produce their own fish as there are no guidelines for their purchases.

Sales to other pisciculturists

There has been considerable trade in eggs and fry between hatcheries in the past. These purchases were usually made by hatcheries having to supply unexpected sales or to replenish stocks depleted by diseases. While some enterprises will continue to periodically require fry to replace losses, the sales of fry are expected to keep on decreasing in the near future. On the other hand, sales of eggs have remained fairly stable over the past five years due to the consistent production of one or two installations. The price of eggs sold by the provincial government has limited the price that private producers can demand, thereby discouraging other enterprises from entering the market. There is some question as to whether private production of eggs should be carried out without assurances being given that proper breeding and disease control programs are followed.

In view of those changes in the traditional inter-hatchery market, many hatcheries will turn towards the expanding fishing pond market, producing larger fish to supply those enterprises located near densely populated areas (Figure 27).

Private ponds

The stocking of private waters, usually ponds, for recreational purposes has long been practiced in Quebec. This activity really started to expand in the 1950's when the provincial government began to encourage the construction and stocking of ponds, particularly in the Eastern Townships (Séguin 1955, Smith 1961). However, the most determinative factor was the availability of pelleted fish food in the 1960's. Until then, ponds had to be stocked sparingly and the fish fed with inconvenient wet foods.

Sales to private pond owners are expected to increase more slowly in the future than they have in the past. Until recently, most purchases were made by people stocking hitherto unused ponds or people wishing to increase their standing stocks because commercial foods made it practicable. Further growth of that market is likely to be subject to the construction of new ponds.

Fishing ponds and retail stores

Pay fishing in private ponds was legalized for rainbow trout in 1969 and for speckled trout in 1978. The sale of rainbow trout in retail outlets was also legalized in 1969, but the retailing of speckled trout on the food market is still forbidden. Pisciculturists feel that the sale of speckled trout to consumers should be permitted; they claim that speckled trout would sell more readily as it is highly valued by consumers. However, many pisciculturists believe that rainbow trout are easier to rear. This belief, coupled with recent changes in regulations, has led to the predominance of rainbow

trout in pay fishing ponds and consequently to an increase in the number of rainbow eggs purchased from governmental hatcheries (Figure 28).

Three hundred metric tons of rainbow trout were imported in Quebec in 1978, which represents 30-40% of total Canadian imports. Retail price of these imports averaged $3.15/Kg in 1977 whereas local producers were asking $5.00/Kg. In 1978, the situation changed due to the devaluation of the Canadian dollar. Retailers were willing to pay up to $4.50/Kg for dressed trout in 1979. However, the price of angled trout was $7.15/Kg in the same year. Therefore, most producers preferred to dispose of their production through the pay fishing market, which is expected to grow rapidly in the near future (Leger 1977). We know of only one fish culture enterprise supplying retailers with portion size rainbow trout on a regular basis. So it will be some time yet before locally produced trout reaches fish counters in significant quantities unless governmental effort is made.

Forecast

Prior to 1978, the production of trout in Quebec ranged from 200 to 300 metric tons. The bulk of that production was sold for recreation. In 1978, 300 metric tons had to be imported to meet the demand of consumers. This demand could amount to 750-1000 metric tons in 1985 (Asselin 1976). Therefore, the Government of Quebec (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation) has proposed a program promoting the construction and improvement of piscicultural installations. By 1985, the production of trout in Quebec could amount to 1000 metric tons. Part of the new production is to be directed towards recreation markets which are not yet saturated, while an increasing proportion of the production is to be directed towards supplying retail outlets.

PROBLEMS AND SOLUTIONS

The rearing of fish is not an easy task, particularly when the producer wishes to make it profitable. Large commercial installations aim at producing the largest number of healthy fish at the lowest cost. This requires knowledge and training. In many instances, fish mortalities have occurred that could have been avoided had the operator had more practical experience, not to mention the efficiency of the operation.

The selection of a site, based on quality and quantity of water, the nature of the terrain and the proximity of markets, is of prime importance when considering fish-culture. Although the quality of water is sometimes unpredictable the proper evaluation of the site can ward off many difficulties. Losses due to high or low temperatures for instance could often have been avoided through careful planning. Pisciculturists have tended to rely upon their own experience to evaluate potential sites; biologists and qualified technicians would be most helpful at that stage.

Accidents, such as mechanical breakdown, flow obstruction and power failure cause the heaviest mortalities (Table 11). Such accidents are usually not predictable. Nevertheless, damages can be limited through careful design of installations by trained personnel. For example, losses due to flow obstruction can be prevented by setting up a low cost alarm.

According to the operators, the next most important cause of mortality is disease, with IPN causing the heaviest losses. Although such disease is bound to spread in intensive culture systems, its incidence could be substantially reduced. Pisciculturists need information on disease prevention, diagnosis and treatment. Their use of chemicals for instance is limited to safer products. Few operators use the more potent therapeutic agents. Where they do, they use low dosages that have little effect. The existence of serotypes of varying virulence needs to be confirmed as does also the existence of immune stocks. It has been recommended already that a province-wide ichthyopathological inventory be undertaken and it seems to us this should be considered with some urgency.

Much concern was expressed about feeds, the cause of loss which ranked third among those reported by pisciculturists. Pisciculturists tend to have little awareness of problems involved in the formulation of adequate feeds, or the ease with which a feed's nutritive value can be altered by improper handling or storage. There is an urgent need for basic research on this subject, as well as for an information or educational program addressed to fish culturists.

Changes in legislation and policies made in recent years have solved many problems of the industry. The MAPAQ for instance has hired personnel specialized in fish-rearing and related fields. It has initiated programs that enable pisciculturists to get financial assistance. Also, a new bulletin ("La Pisciculture québécoise") is published regularly that provides those interested with popular biological and technological information as well as progress reports on current matters.

In order to make the future of the fish-culture industry in Quebec more prosperous, further steps will have to be taken. Pertinent courses and laboratory work should be included in CEGEP programs (Technicien (ne) en agriculture or Technicien (ne) de la faune) to provide beginners with basic knowledge. Biologists, fish health specialists and technicians are also needed in regions to assist pisciculturists in site evaluation, disease control and treatment, and to help them improve their

methods. Finally, the selection and genetic improvement of stocks and the perfection of technology should be carried out through fundamental research programs. Original solutions have to be found to solve problems that are specific to Quebec.

POLLUTION

In Denmark, Davis (1979) estimated that 35% of total organic matter discharged in mainland waterways originated from fish farms. Such a load is equivalent to that from a population of half a million people. Similarly, the BOD production in salmonid rearing installations of the United States is high, comparable with that of two million people (Liao 1972).

Little is known about the polluting effects of fish culture in Quebec. This survey suggests that the impact is negligible but for a few exceptions. Indeed, discharged water sometimes is purer than incoming water, particularly in fishing ponds. Cases of eutrophication due to cultured fish production practices have been reported by Hinshaw (1973), Szluha (1974), Aquafarms Canada (1977) and Bergheim and Selmer-Olsen (1979). In Quebec, several cases of eutrophication within rearing basins were observed during this survey. However, since the receiving waters are oligotrophic, current levels of nutrient loadings are most likely beneficial. In the authors' opinion, such levels are not likely to adversely affect the fish populations of receiving waters, except where improper cleaning and draining procedures are followed.

Traditionally, water was used lightly in order to maintain dissolved oxygen levels above 5 mgL^{-1} (Boulanger 1978). Therefore, fish-cultural activities had little bearing on the quality of receiving waters. However, the introduction of techniques for the aeration of water coupled with a greater understanding of fish physiology, have promoted the more intensive use of water supplies with the result that the nutrient load of water increases up to ten-fold when water is recirculated. Disposal of these nutrient-rich waters, especially if the overall quantity is significantly increased, should be closely controlled and monitored in order to minimize their potential negative impact on the quality of the environment.

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Table 1. Species cultured in Quebec

Common name	Scientific name	Date cultured	Note
Atlantic salmon	Salmo salar	1858 to present	Richard Nettle
Ouananiche	Salmo salar	1930 to present	
Speckled trout	Salvelinus fontinalis	1857 to present	Richard Nettle
Arctic char (Quebec red trout)	Salvelinus alpinus	1968[a]	
Lake trout	Salvelinus namaycush	1881[b] to present	Originally from Great Lakes
Dolly Varden	Salvelinus malma		Never stocked
Splake[c]	S. fontinalis (M) x S. namaycush (F)	1945 to present[a]	
Rainbow trout[d]	Salmo gairdneri	1903 to present	
Brown trout[d]	Salmo trutta	1890[b] to present	
Cutthroat trout[e]	Salmo clarki	1940[b]- 1970[b]	
Chinook salmon[e]	Oncorhynchus tshawytscha	1876 - 1878	
Sockeye, kokanee salmon	Oncorhynchus nerka	1890 and 1968	
Pink salmon	Oncorhynchus gorbuscha	1968	From neighbouring provinces
Coho salmon[e]	Oncorhynchus kisutch	1970's	From neighbouring provinces
Danube salmon	Hucho hucho	1967 - 1970's[a]	

Table 1. Species cultured in Quebec (continued).

Common name	Scientific name	Date cultured	Note
Arctic grayling	Thymallus arcticus	1968	
Whitefish[c]	Coregonus clupeaformis	1876-1968	Originally from Great Lakes
Cisco	Coregonus artedii	1968	
Smelt	Osmerus mordax	1935[a]	
Muskellunge	Esox masquinongy	1932 to present	
Yellow perch[c]	Perca flavescens	1937- ?	
Yellow walleye[c]	Stizostedion vitreum	1965- ?	
Smallmouth bass[c]	Micropterus dolomieui	1924- ?	Captured fry
Largemouth bass[c]	Micropterus salmoides	1965- ?	
Carp	Cyprinus carpio	1950	Used as food for muskellunge
Goldfish	Carassius auratus	?	

a- date uncertain
b- approximate date
c- culture done occasionally
d- successful introduction
e- unsuccessful introduction

Table 2a. Numbers of rainbow and brown trout stocked by the Province of Quebec's hatchery system from 1917 to 1977.

Year	Rainbow trout			Brown trout		
	Fry	Fingerling	Yearling	Fry	Fingerling	Yearling
1917	680,000					
1920	335,000	38,000				
1921	?	?	?			
1922	325,000					
1923	?	?	?			
1924	955,000	103,000				
1925	1,175,000					
1926	1,000,000	10,000				
1927	480,000	38,000				
1928	355,000					
1929	?	?	?			
1930	175,000	36,000	14,150			
1931	100,000	120,000				
1932	?	?	?			
1933	33,000	172,000	5,600			
1934	90,000	118,000	7,000			
1935	30,000					2,000
1936	?	?	?			
1937	50,000	212,000	1,000			
1938	99,000	193,686				
1939	125,000	414,500				
1940	42,000	472,000	1,600			
1941		149,000	4,150			
1942	13,000	31,000	75			
1945	10,000					
1951		11,000			11,000	
1952	31,000	55,600	2,226	65,000	27,100	1,800
1953		22,050	2,120	65,000	15,131	3,000
1954	355,000	107,500	167	18,000	22,900	225
1955	168,000	56,565	36,737	5,000	25,550	500
1956	310,980	74,500	12,778	252,000	329,596	5
1957	190,200	35,700	289	77,063	32,678	335
1958	169,243	61,228	4,515	141,205	31,897	976
1959	219,200	112,000	3,177	252,000	109,681	2,000
1960	68,000	37,012		141,698	86,050	
1961	120,525	64,638		22,000	40,035	10,147
1962	92,600	39,409	3,907		30,528	5,740
1963	12,307	22,538	995	13,000	2,743	9
1964	68,000	87,681		238,000	62,561	

Table 2a. Numbers of rainbow and brown trout stocked by the Province of Quebec's hatchery system from 1917 to 1977 (continued).

Year	Rainbow trout Fry	Rainbow trout Fingerling	Rainbow trout Yearling	Brown trout Fry	Brown trout Fingerling	Brown trout Yearling
1965	82,000	62,767	1,500	118,000	53,356	721
1966	year's total:	211,377		year's total:	51,500	
1967	36,500	127,310	15,319	39,000	87,750	1,559
1968	151,500	89,379	302	26,500	82,806	2,147
1969	145,000	43,000	11,314	50,000	73,500	3,000
1970	182,000	113,000	7,500	116,225	110,000	1,900
1971	112,750	108,300	17,278		123,000	700
1972	year's total:	896,560		year's total:	244,546	
1973	66,500	200,050	30,250	30,000	162,650	32,250
1974	131,500	117,500	115,577	30,000	80,000	48,860
1975	81,500	87,000	50,037	22,015	48,000	12,000
1976	85,000	80,000	64,987	37,000	121,000	59,258
1977	50,000	133,000	76,366	312,000	181,000	27,231
Total:	9,001,305	4,055,913	490,916	2,070,706	1,950,512	216,363

Table 2b. Numbers of other exotic salmonids stocked by the Province of Quebec's hatchery system from 1968 to 1977.

Species	Year	Fry	Fingerling	Yearling
Cutthroat	1968		620	
Kokanee	1968	40,000		
Danube salmon	1968	11,000	675	
Danube salmon	1969			519
Cutthroat	1971		220	1,024
Danube salmon	1973			900
Cutthroat	1974			95
Cutthroat	1975			82
Cutthroat	Total		840	1,201
Kokanee	Total	40,000		
Danube salmon	Total	11,000	675	1,419

Table 3. Water tests: parameters, methods and apparatus, precision.

Parameter	Method and apparatus	Precision	Remarks
Temperature	Fisher pocket thermometer YSI Model 57 meter	1 C 1 C	Checked with certified mercury thermometer
pH	Fisher Accumet Model 150 pH meter Fisher Brand Model 107 pH meter	0.1 0.5	
Dissolved oxygen	YSI Model 57 dissolved oxygen meter	1%(ppm)	Checked with Winkler method
Carbon dioxide	Bausch and Lomb Spectrokit Reagent System	2 mg L^{-1}	
Ammonia nitrogen	Bausch and Lomb Spectronic mini 20 spectrophotometer and Spectrokit Reagent System	0.1 mg L^{-1}	
Nitrate nitrogen	Bausch and Lomb Spectronic mini 20 spectrophotometer and Spectrokit Reagent System. Cadmium reduction method	0.1 mg L^{-1}	
Nitrite nitrogen	Bausch and Lomb Spectronic mini 20 spectrophotometer and Spectrokit Reagent System. Deazotization method	0.01 mg L^{-1}	
Chloride	Bausch and Lomb Spectrokit Reagent System	20 mg L^{-1}	
Orthophosphate	Bausch and Lomb Spectronic mini 20 spectrophotometer and Spectrokit Reagent System. Ascorbic acid method	0.5 mg L^{-1}	
Soluble iron	Bausch and Lomb Spectronic mini 20 spectrophotometer and Spectrokit Reagent System. 1,10- Phenanthroline method	0.1 mg L^{-1}	
Alkalinity as $CaCO_3$	Bausch and Lomb Spectrokit Reagent System	20 mg L^{-1}	
Hardness as $CaCO_3$	Bausch and Lomb Spectrokit Reagent System	20 mg L^{-1}	

Table 4. Regional distribution of private fish-culture installations in 1978. The number of installations surveyed is given in parentheses.

	Region	Category I	Category I + Fishing pond	Fishing pond	Category II	Total
I	Northwest Quebec	7(6)	23(19)	5(-)	11(-)	45(27)*
II	St. Lawrence Lowlands	2(2)	15(15)	5(1)	22(-)	44(18)
III	Eastern Townships	6(5)	29(21)	4(-)	17(2)	56(29)*
IV	Beauce	4(4)	15(14)	9(4)	12(-)	40(22)
V	Northeast Quebec	6(4)	17(12)	3(1)	15(-)	40(17)
VI	Gaspé	4(2)	7(5)	2(-)	13(1)	26(9)*
Total		29(23)	106(86)	28(6)	90(3)	253(122)*

* These totals include four installations operating in 1978 which had not renewed their 1977 licences.

Table 5. Distribution of private fish-culture installations in hydrographic areas and drainage basins.

Hydrographic* area	Drainage* basin	Number of installations	Total
01	Daaquam	1	1
02	Des Trois Pistoles	3	
	Verte	3	
	Du Sud	4	
	Etchemin	4	
	Chaudière	3	
	Ruisseau Bourret	1	
	Bécancour	2	20
03	Nicolet	7	
	Saint-François	26	
	Yamaska	11	
	Richelieu	4	48
04	Ottawa	2	
	Du Nord	2	
	Rouge	5	
	Du Lièvre	1	
	Gatineau	4	
	Quyon	1	
	Des Outaouais (Upper)	3	18
05	L'Assomption	2	
	Chicot	1	
	Du Loup	4	
	Champlain	1	
	Batiscan	2	
	Saint-Charles	2	
	Sainte-Anne du Nord	2	
	Yamachiche	1	
	Saint-Maurice	3	18
06	A Mars	1	
	Saguenay	1	2
08	Harricana	1	
	La Sarre	1	2
Others	St. Lawrence	10	
	Connecticut River (U.S.A.)	1	

* Hydrographic areas and drainage basins are as defined by Ministère des Richesses Naturelles du Québec (Map 021, 1975).

Table 6. The age (years) of private fish-culture installations surveyed in 1978.

Region	1-2	3-5	6-10	11-15	16-20	21-25	26-30
I	1	10	5	7	1	-	3
II	6	9	1	1	1	-	-
III	4	10	8	4	3	-	-
IV	5	9	5	1	2	-	-
V	5	5	5	1	-	1	-
VI	-	2	4	3	-	-	-
Total	21	45	28	17	7	1	3

Table 7. Individuals employed in 122 private fish-culture installations in 1978.

Region	Hobby owners	Self employed	Part-time employees	Full-time employees
I	6	17	9	17
II	8	10	4	3
III	10	21	7	1
IV	11	12	10	5
V	6	12	5	4
VI	3	2	2	1
Total	44	74	37	31

Table 8. Species of fish raised in private fish-culture installations in 1978.

Region	Number of respondents	Speckled trout	Rainbow trout Spring	Rainbow trout Fall	Lake trout	Bait fish
I	27	23	19	10	6	-
II	18	13	13	4	-	-
III	28	23	16	7	-	1
IV	22	19	11	2	-	-
V	17	14	10	2	1	-
VI	10	8	3	-	-	-
Total	122	100	72	25	7	1

Table 9. Production and sales of eggs (in thousands) between fall 1977 and spring 1978. The figures in parentheses represent the number of sales.

Species	Region	Number of hatcheries	Produced from broodstock of private hatcheries	Purchased from private hatcheries	Purchased from MLCPQ hatcheries
Speckled trout	I	13	350(2)	1,515(7)	1,785(9)
	II	6	200(1)	200(1)	470(5)
	III	16	3,525(3)	390(6)	680(9)
	IV	9	4,240(6)	660(5)	50(1)
	V	10	2,135(2)	350(2)	1,150(6)
	VI	6	97(2)	410(3)	130(2)
	Total	60	10,547(16)	3,525(24)	4,265(32)
Rainbow trout (spring)	I	11	515(3)	-	860(10)
	II	1	-	-	60(1)
	III	10	10(1)	-	555(9)
	IV	7	125(1)	-	625(6)
	V	2	-	-	280(2)
	VI	-	-	-	-
	Total	31	650(5)	-	2,380(28)
Rainbow trout (fall)	I	5	-	-	585(5)
	II	3	-	-	300(3)
	III	4	-	-	235(4)
	IV	1	-	-	50(1)
	V	2	-	-	150(2)
	VI	-	-	-	-
	Total	15	-	-	1,320(15)
Lake trout	I	6	-	-	123(6)
	V	1	-	-	55(1)
	Total	7	-	-	178(7)

Table 10a. Sales of salmonids in 1977: speckled trout.

Stage	Region	Number of hatcheries	Type of sales *							Total sales	Range
			A	B	C	D	E	F	X		
Alevin	I	8	6	7	1					747,365	6,000 - 250,000
	II	3	1	2	2					239,000	35,000 - 104,000
	III	9	1	8	1					349,000	2,000 - 150,000
	IV	7	2	6	2					1,527,500	500 - 1,096,000
	V	5	3	4					1	525,000	5,000 - 340,000
	VI	3		3						24,500	3,500 - 15,000
	Total	35	13	30	6				1	3,412,365	500 - 1,096,000
Fingerling	I	10	9	6	1					1,184,000	8,000 - 350,000
	II	2		1	1					20,000	5,000 - 15,000
	III	7	2	6						120,000	1,000 - 30,000
	IV	6	2	5	2					174,435	600 - 100,000
	V	7	5	6						161,000	3,000 - 60,000
	VI	4		3					1	137,500	7,500 - 60,000
	Total	36	18	27	4				1	1,796,935	600 - 350,000
Yearling and older	I	8	1	3	1	3				67,328	50 - 32,000
	II	5		1		4				11,900	1,000 - 5,500
	III	12		2	3	7	1			49,000	100 - 15,000
	IV	10	2	4	3	5				120,023	450 - 50,000
	V	3	1	2		2				67,000	2,000 - 51,000
	VI	2	1	1		2				34,000	6,000 - 28,000
	Total	40	5	13	7	23	1			349,251	50 - 51,000

* A Sales to fishing clubs for stocking on leased land
B Sales for stocking on private properties
C Sales to other private fish-culture enterprises
D Sales of fish angled in fishing ponds
E Sales of fish for human consumption
F Sales of fish for bio-assays
X No explanation given

Table 10b. Sales of salmonids in 1977: rainbow trout.

Stage	Region	Number of hatcheries	Type of sales							Total sales	Range
			A	B	C	D	E	F	X		
Alevin	I	5	1	4					1	92,300	10,000 - 25,000
	II	1	1							76,000	
	III	3		3						170,000	10,000 - 150,000
	IV	3		3	1					205,200	2,500 - 200,000
	V	4		3	1			1		96,000	1,000 - 60,000
	Total	16	2	13	2			1	1	639,500	1,000 - 200,000
Fingerling	I	5		4					1	69,122	1,000 - 20,000
	II	1						1		200	
	III	7		7						62,000	2,000 - 30,000
	IV	2		1	1					62,500	30,000 - 32,500
	V	1		1						16,000	
	Total	16		13	1			1	1	209,822	200 - 32,500
Yearling and older	I	9		2	1	5	2			199,216	350 - 85,000
	II	5				3	1		1	37,500	1,100 - 16,000
	III	10		3	2	5	2			58,388	2,000 - 20,000
	IV	5		2	1	2			1	62,200	200 - 55,500
	V	9		1	2	7	1			115,624	500 - 43,500
	VI	1		1		1				6,068	
	Total	39		9	6	23	6		2	478,996	200 - 85,000

Table 10c. Sales of salmonids in 1977: lake trout.

Stage	Region	Number of hatcheries	Type of sales							Total sales	Range
			A	B	C	D	E	F	X		
Alevin	I	2		2						25,000	5,000 - 20,000
	V	1	1	1						50,000	
	Total	3	1	3						75,000	5,000 - 50,000
Fingerling	I	4	1	4						72,725	9,000 - 34,000

Table 11. Losses reported.

Species	Region	Number of respondents	Alevins 0	Alevins 25	Alevins 50	Alevins 75	Fingerlings 0	Fingerlings 25	Fingerlings 50	Fingerlings 75	Yearlings 0	Yearlings 25	Yearlings 50	Yearlings 75	Two years and older 0	Two years and older 25	Two years and older 50	Two years and older 75
			24	49	74	100%	24	49	74	100%	24	49	74	100%	24	49	74	100%
Speckled	I	16	7	7	1		12	1			9							
trout	II	9	2	4		2	5	1			4	2			3			
	III	18	8	5	2		13			1	12			1	3			1
	IV	18	6	3	1	4	10				8				6	1		
	V	13	1	2	2	5	11	1			9				6			
	VI	4	2	2			1				1				1			
	Total	78	26	23	6	11	52	3		1	43	2		1	19	1		1
Rainbow	I	12	5	1	1	1	5	2			6				1			
trout	II	7	1	2			5	1			2	1			1			
(spring)	III	10	8	7	1	1	9	1	1		8		1		4			
	IV	6	4	1		1	5				3	1			4			
	V	9	3	2	1		7				7				6			
	VI	1					1				1							
	Total	45	21	13	3	3	32	4	1		27	2	1		16			
Rainbow	I	6	3	2	1		4				3							
trout	II	3	1			1	1	1		1	1	1			1			
(fall)	III	5	2			3	4			1	4				1			
	V	2	1	1			2				2							
	Total	16	7	3	1	4	11	1		2	10	1			2			
Lake trout	I	5	5				5				1							

Table 12. Distribution of brood fish in regions.

Species	Region	1 year	2 year	3 year	4 year	5 year	Number of installations
Speckled trout	I	300	150	1500			4
	III	1760	1530	1030			3
	IV	3500	2400	880	100		6
	V	100	4500		900		4
	Total	5660	8580	3410	1000		17
Rainbow trout (spring)	I			385	200	150	4
	III	30	30	30			1
	IV	1000	200	425	75		2
	V		100				
	Total	1030	330	840	275	150	8

Table 13. Causes of loss.

Cause	Region I		Region II		Region III	
	Responses	Loss	Responses	Loss	Responses	Loss
Accident	6 (18%)		3 (13%)		9 (22%)	
Flow obstruction	1 (3%)				2 (5%)	48% (2)
Mechanical breakdown	1 (3%)		1 (4%)	30% (1)		
Electrical failure	2 (6%)		1 (4%)		4 (10%)	90% (1)
Floods	1 (3%)					
Neighbours					1 (2%)	
Unspecified	1 (3%)		1 (4%)	100% (1)	2 (5%)	62% (2)
Feed	1 (3%)		1 (4%)		4 (10%)	100% (1)
Disease	6 (18%)		4 (17%)		5 (12%)	
IPN	2 (6%)	40% (1)	1 (4%)	40% (1)	1 (2%)	60% (1)
Fungus			1 (4%)			
BGD	3 (9%)		1 (4%)		3 (7%)	24% (2)
Unknown	1 (3%)	40% (1)	1 (4%)	5% (1)	1 (2%)	
Predation	10 (29%)		6 (26%)		10 (24%)	
Kingfisher						
Heron			1 (4%)	10% (1)		
Mink and otter					2 (5%)	
Unspecified	10 (29%)	5% (2)	5 (22%)		8 (20%)	5% (2)
Water quality	3 (9%)		3 (13%)		7 (17%)	
Improper pH						
Low temperatures			1 (4%)	100% (1)	1 (2%)	25% (1)
High temperatures	2 (6%)		1 (4%)		6 (15%)	45% (2)
Iron	1 (3%)					
Supersaturation						
General			1 (4%)			
Unknown	4 (12%)	88% (2)	1 (4%)	50% (1)	1 (2%)	50% (1)
Inexperience	4 (12%)		5 (22%)	55% (2)	4 (10%)	95% (1)
Theft					1 (2%)	100% (1)
Number of respondents	22		15		23	
Number of responses	34		23		41	

Table 13. Causes of loss (continued).

Cause	Region IV		Region V		Region VI	
	Responses	Loss	Responses	Loss	Responses	Loss
Accident	5 (14%)		1 (4%)		1 (8%)	
Flow obstruction	1 (3%)	20% (1)				
Mechanical breakdown	3 (9%)	23% (3)			1 (8%)	50% (1)
Electrical failure	1 (3%)	25% (1)				
Floods						
Neighbours						
Unspecified			1 (4%)	11% (1)		
Feed	5 (14%)	64% (4)	3 (12%)	90% (1)	1 (8%)	
Disease	6 (17%)		7 (28%)		5 (38%)	
IPN	1 (3%)	70% (1)	5 (20%)	90% (1)	3 (23%)	50% (1)
Fungus	1 (3%)	5% (1)				
BGD	2 (6%)		2 (8%)		2 (15%)	
Unknown	2 (6%)	5% (2)				
Predation	9 (26%)		7 (28%)		3 (23%)	
Kingfisher	1 (3%)		1 (4%)	5% (1)		
Heron						
Mink and otter			1 (4%)			
Unspecified	8 (23%)	22% (5)	5 (20%)	17% (4)	3 (23%)	20% (1)
Water quality	4 (11%)		4 (16%)		2 (15%)	
Improper pH			1 (4%)	10% (1)		
Low temperatures	1 (3%)	20% (1)	1 (4%)	15% (1)		
High temperatures						
Iron	1 (3%)					
Supersaturation	2 (6%)	50% (1)	1 (4%)		2 (15%)	30% (1)
General			1 (4%)			
Unknown				55% (2)		
Inexperience	4 (11%)				1 (8%)	
Theft	2 (6%)	100% (1)				
Number of respondents	16		14		7	
Number of responses	35		25		13	

Table 13. Causes of loss (continued).

Cause	Number of responses	%	Production lost
Accident	25	15	44% (14)
Flow obstruction	4	2	38% (3)
Mechanical breakdown	6	4	30% (5)
Electrical failure	8	5	58% (2)
Floods	1	.6	
Neighbours	1	.6	
Unspecified	5	3	59% (4)
Feed	15	9	74% (6)
Disease	33	19	35% (13)
IPN	13	8	58% (6)
Fungus	2	1	5% (1)
BGD	13	8	24% (2)
Unknown	5	3	14% (4)
Predation	45	26	14% (16)
Kingfisher	2	1	5% (1)
Heron	1	.6	10% (1)
Mink and otter	3	2	
Unspecified	39	23	15% (14)
Water quality	23	14	38% (9)
Improper pH	1	.6	10% (1)
Low temperatures	4	2	40% (4)
High temperatures	9	5	45% (2)
Iron	2	1	
Supersaturation	5	3	40% (2)
General	2	1	
Unknown	8	5	64% (6)
Inexperience	19	11	68% (3)
Theft	3	2	100% (2)
Number of respondents	97		
Number of responses	171		

Table 14. Chemical products used by private fish-culturists.

Product	Use	Regions						Total
		I	II	III	IV	V	VI	
Malachite green	Fungus control	11	6	13	9	8	2	49
Salt	Tonic	10	4	8	6	6		34
Formalin	Tonic	4	1	1	4	2	1	13
Vitamin supplements	Growth	2		1	1			4
Copper sulfate	Fungus control	2			1			3
Cutrine	Algal control	1		1				2
Antibiotics	Bacterial diseases	1		1				2
Roccal	Bacterial gill disease			1				1
MS222	Anaesthetic			1				1
Quaternary ammonium	Disinfectant	1						1
Stabilized chlorine	Disinfectant			1				1
Nothing				4			1	5
Total number of responses		32	11	32	21	16	4	116
Total number of respondents		15	7	20	10	8	3	63

Table 15. Feeds used by private fish-culturists.

Brand or food item	Region						Total
	I	II	III	IV	V	VI	
Purina	19	16	22	19	15	8	99
Ewos	12	6	3	4	5	1	31
Rose Brand	2		1	2	3	1	9
Agway		2	6	1			9
Silver cup				1	2	1	4
Co-op	1				1		2
Liver	8	5	14	9	7	2	45
Dried shrimp			1	1			2
Frozen fish				1			1
Respondents using 1 feed	12	8	10	8	8	4	50
Respondents using 2 feeds	9	6	7	6	4	4	36
Respondents using 3 feeds	4	3	8	6	5		26
Total number of respondents	25	17	25	20	17	8	112
Total weight (tons) of feed purchased	168.68	31.61	63.55	58.20	41.08	10.17	373.29

Table 16. Sources of water.

Source	Region						Total
	I	II	III	IV	V	VI	
Spring							
Number of enterprises	16	8	13	16	9	8	70
Number of springs	29	15	30	31	11	10	126
Temperature rance (C)	3-5	2-12	3-13	2-15	3-14	0-20	0-20
Flow range ($L M^{-1}$)	30-10500	45-900	14-450	36-1000	75-2250	14-360	14-10500
Pumped wells							
Number of enterprises	4	7	13	8	4	1	37
Number of wells	9	16	21	13	4	1	64
Temperature range	?	7-9	6-10	6-15	5-9	?	6-15
Flow range	158-450	23-230	9-230	38-450	18-230	?	9-450
Artesian wells							
Number of enterprises	5	2	2	4	1	1	15
Number of wells	11	5	3	13	1	1	34
Temperature range	8-10	?	6-9	6-7	?	?	6-10
Flow range	32-140	99	113	?	18	?	18-140
Brooks, creeks etc.							
Number of enterprises	10	6	15	9	8	3	51
Number of brooks	12	6	18	12	11	3	62
Temperature range	0-25	0-16	0-27	0-25	0-22	0-24	0-27
Flow range	72-13500	0-360	68-4500	450-9000	270-13500	?	0-13500
Water table							
Number of enterprises	1	2		1			4
Temperature range	2-9	10-18		?			2-18
Flow range	1-125	36		378			1-378
City water							
Number of enterprises			1		2		3
Temperature range			?		2-11		2-11
Flow range			?		27-9000		27-9000
Using one source	15	9	8	8	8	3	51
Using two sources	7	5	10	8	5	3	38
Using three sources	6	2	5	4	3	1	21
Using four sources or more		1	6	2	1	1	11

Table 17. Water recirculation.

Region	Number of respondents	Number of respondents recirculating water	Percentage recirculated	Range (%)
I	27	4 (15%)	66 (2)	-
II	17	10 (59%)	63 (5)	25-90
III	25	9 (36%)	60 (8)	25-90
IV	22	12 (55%)	54 (6)	10-80
V	17	5 (29%)	44 (4)	10-75
VI	8	5 (62%)	32 (2)	15-50
Total	116	45 (39%)	55 (27)	10-90

Table 18. Temperature control.

Region	Number of respondents	Number of respondents heating water
I	27	8 (30%)
II	17	0 (0%)
III	25	3 (12%)
IV	22	3 (14%)
V	17	1 (6%)
VI	8	2 (25%)
Total	116	17 (15%)

Table 19. Water aeration.

Method of aerating	Region						Total
	I	II	III	IV	V	VI	
Falls	11	1	8	3	4		27
Surface agitation	2	1	2	2		1	8
Pumps	1	7	10	10	2	1	31
Venturi	1		1		1		3
Diffusor	1		1	4		3	9
Unspecified		1					1
Number of respondents	27	17	25	22	17	8	116
Number of respondents aerating water	13	10	18	15	6	5	67

Table 20. Pumps

Variable	Region						Total
	I	II	III	IV	V	VI	
Number of respondents	27	17	25	22	17	8	116
Number of respondents using pumps	9 (33%)	14 (82%)	20 (80%)	19 (86%)	9 (53%)	3 (38%)	74 (64%)
Number of pumps	39	58	104	82	27	5	315
Minimum power (H.P.)	1/3	1/4	1/3	1/3	1/3	1/3	1/4
Maximum power (H.P.)	5	3	5	25	15	1	25

Table 21. Backup systems.

System	Region						Total
	I	II	III	IV	V	VI	
Generator	6	9	9	6	4	3	37
Alarm	4	3	3	1	2	1	14
Pump	3	2	9	6	5		25
Number of respondents	27	17	25	22	17	8	116
Number of respondents with backup system	8 (30%)	9 (53%)	15 (60%)	10 (45%)	9 (53%)	3 (38%)	54 (47%)

Table 22. Upstream activities.

Activity	Region						Total
	I	II	III	IV	V	VI	
Pisciculture			1		1		2
Forestry	7	3	14	14	9	5	52
Agriculture	12	11	14	10	6	1	54
Mining		1	1	1			3
Industry		1					1
Residences	11	5	7	2	8		33
None	2	2	2	1		2	9
Two activities	3	3	6	7	7		26
Three activities	1	1	4				6
Number of respondents	27	17	25	22	17	8	116

Table 23. Rearing equipment

Equipment	Region						Total
	I	II	III	IV	V	VI	
Number of respondents	26	17	25	19	17	7	111
Number of troughs	449	149	208	138	288	32	1264
Number of enterprises	17	9	19	10	11	6	72
Range in number per site	3-80	1-40	1-40	1-29	4-104	2-7	1-104
Number of tanks	54	30	16	29	107	8	244
Number of enterprises	11	6	4	7	11	2	41
Range in number per site	1-12	3-8	2-6	1-9	2-37	2-6	1-37
Number of earthen raceways	37	13	9	19	32	3	113
Number of enterprises	10	5	3	5	5	2	30
Range in number per site	2-7	2-4	1-4	1-8	1-11	1-2	1-11
Number of concrete raceways	115	4		15	1		135
Number of enterprises	11	1		3	1		16
Range in number per site	1-28	4		1-8	1		1-28
Number of circular ponds	24	9	45	33	44	6	161
Number of enterprises	6	5	11	10	5	2	39
Range in number per site	1-8	1-3	2-9	1-7	2-30	2-4	1-30
Number of ponds	61	44	96	43	37	17	298
Number of enterprises	21	15	24	17	13	5	95
Range in number per site	1-6	1-9	1-8	1-6	1-7	1-8	1-9
Vertical flow incubators	8		6			1	15
Number of enterprises	3		1			1	5
Range in number per site	1-6		6			1	1-6

Table 24. Opinions of managers as to whether they feel they are exploiting their site to the maximum.

Region	Yes	No	Number of respondents
I	5 (28%)	13 (72%)	18
II	3 (30%)	7 (70%)	10
III	4 (21%)	15 (79%)	19
IV	1 (10%)	9 (90%)	10
V	1 (12%)	7 (88%)	8
IV		4	4
Total:	14 (20%)	55 (80%)	69

Table 25. Opinions of managers as to whether they can calculate their profit margin.

Region	Yes	No	Number of respondents
I	5 (71%)	2 (29%)	7
II		3	3
III	2 (22%)	7 (78%)	9
IV	1 (14%)	6 (86%)	7
V	1 (20%)	4 (80%)	5
VI	3 (75%)	1 (25%)	4
Total:	12 (34%)	23 (66%)	35

Table 26. Comments concerning the establishment of zone restrictions.

Region	Number of respondents	A	B	C	D	E	F	G	H	I
I	6		3	1	1	1	1			
II	3	1	1	1						
III	13	1	6	3		2	1			
IV	4		1	2			1		1	
V	6		2	1		1	1	1		
VI	1									1
Total:	33	2	13	8	1	4	4	1	1	1

A- Respondents feel that the change in laws concerning speckled trout has more than compensated for any bad effect of zone restrictions.

B- There has been no effect.

C- The effect of zone restrictions is unknown.

D- Respondents claim that zone restrictions have failed to solve the problems concerning the stocking of rainbow trout by private enterprises.

E- New laws required that they change species formerly cultured.

F- Respondents feel they have lost potential customers in restricted areas.

G- Respondents claim an increase in competition from operations switching from ranbow to speckled trout.

H- Respondents claim loss of sales of rainbow to customers no longer permitted to keep them.

I- Restrictions forced closure of the operation.

Table 27. Comments concerning the declubbing of leased lands.

Region	Number of respondents	A	B	C	D	E	F	G	H	I
I	11	3		1	3	1			2	3
II	5	1	1		1				1	3
III	16	7	3		4		1	1		3
IV	8	1	2	2	4			1		3
V	6	3	2	1						
VI										
Total:	46	15	8	4	12	1	1	2	3	12

A- There has been no effect.

B- The effect is not yet known.

C- Respondents feel that they have lost potential expansion.

D- Respondents must change their type of production.

E- The market is unstable and unfavourable for investment as a result of declubbing.

F- The number of pay-fishermen has decreased due to an increase in available fishing sites.

G- Respondents claim an increase in competition on the remaining market.

H- Respondents feel that the compensating purchases offered them are insufficient.

I- Respondents claim they have suffered a loss of past sales to clubs or to fish-culture enterprises that supplied clubs in 1977-1978.

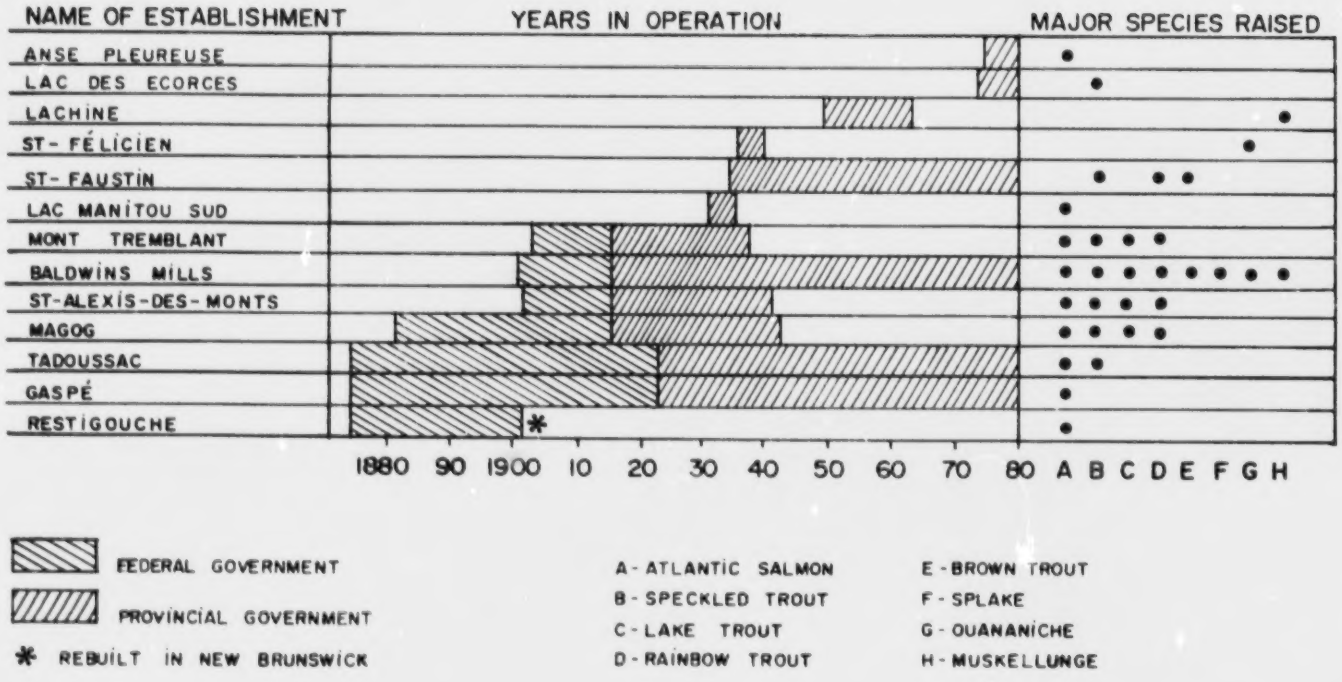

Figure 1. Governmental fish culture establishments in Quebec: 1875-1980.

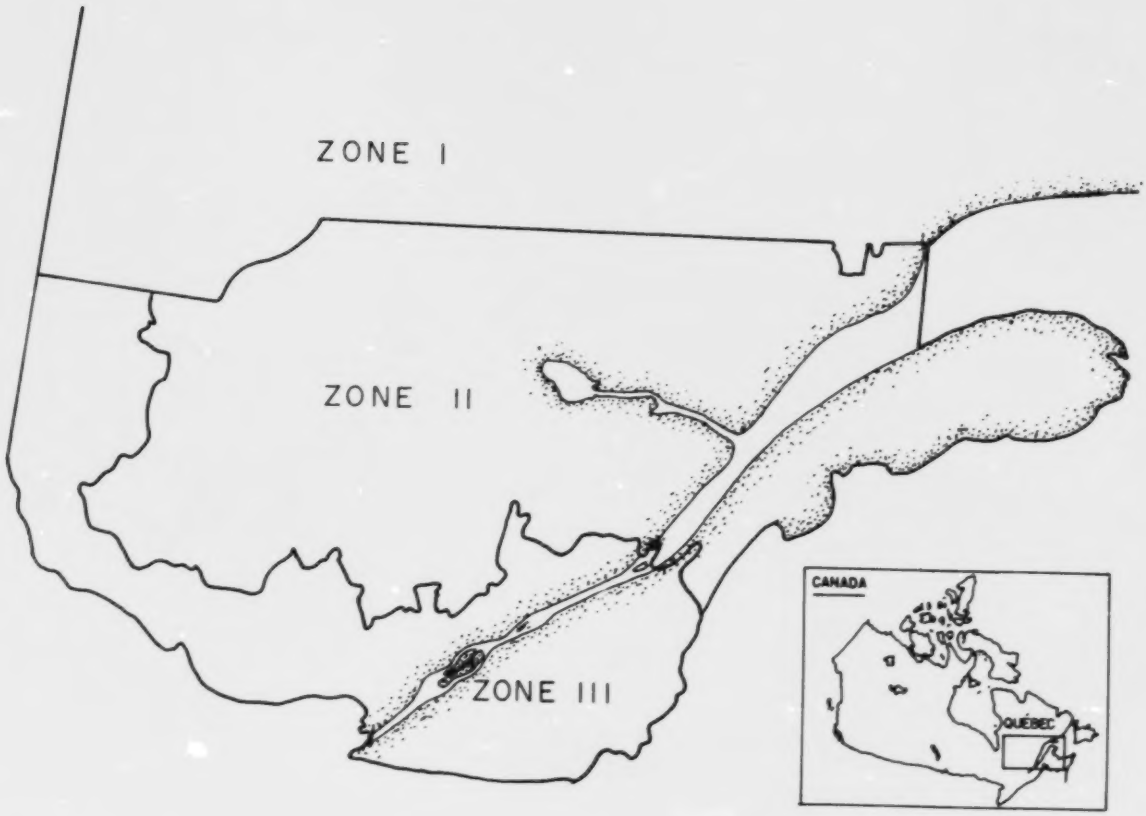

Figure 2. Piscicultural zones. Zone I, stocking and culture forbidden. Zone II, stocking and culture of exotic species forbidden. Zone III, permit required for the stocking of exotic species; no restriction on culture.

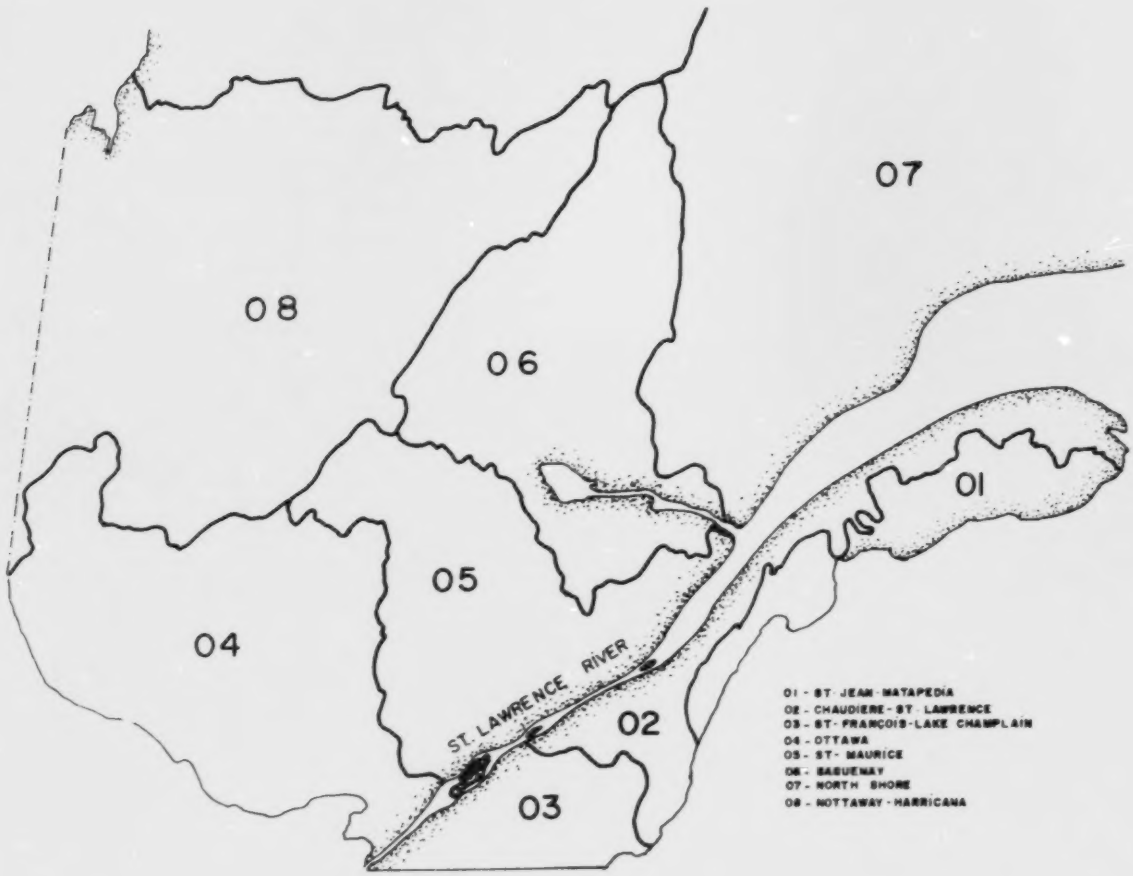

Figure 3. Hydrographic areas.

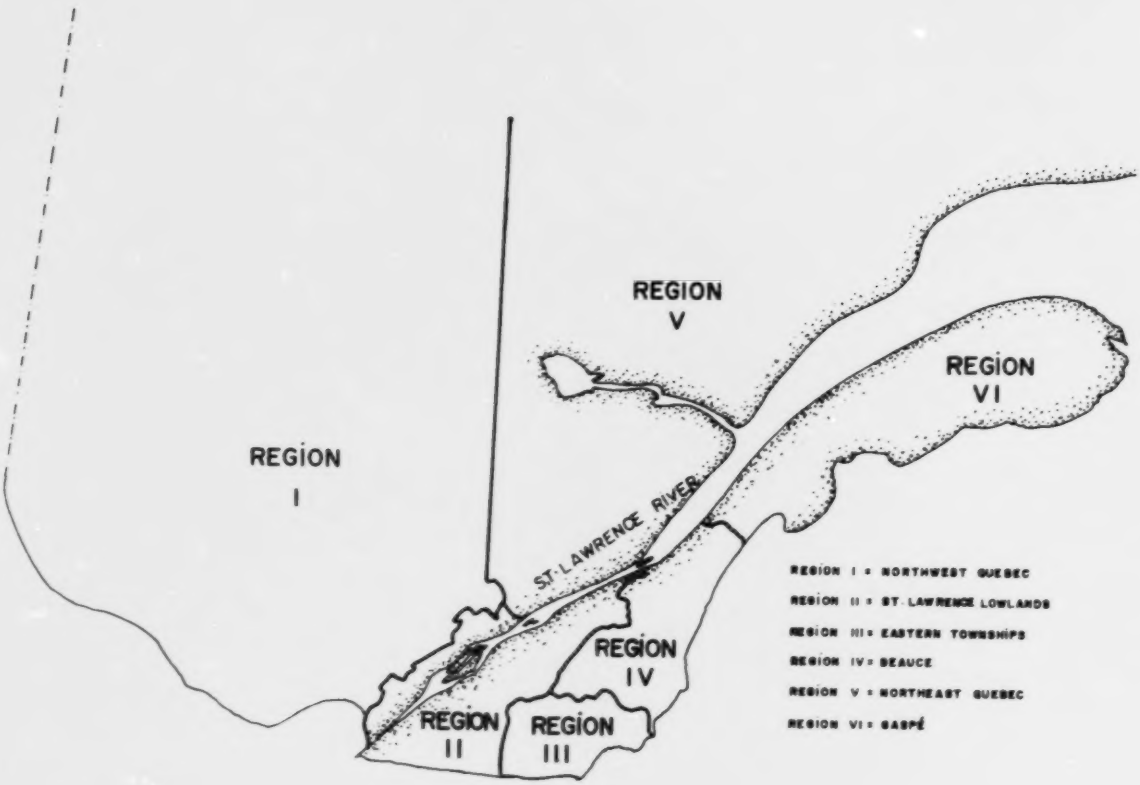

Figure 4. Fish-culture regions.

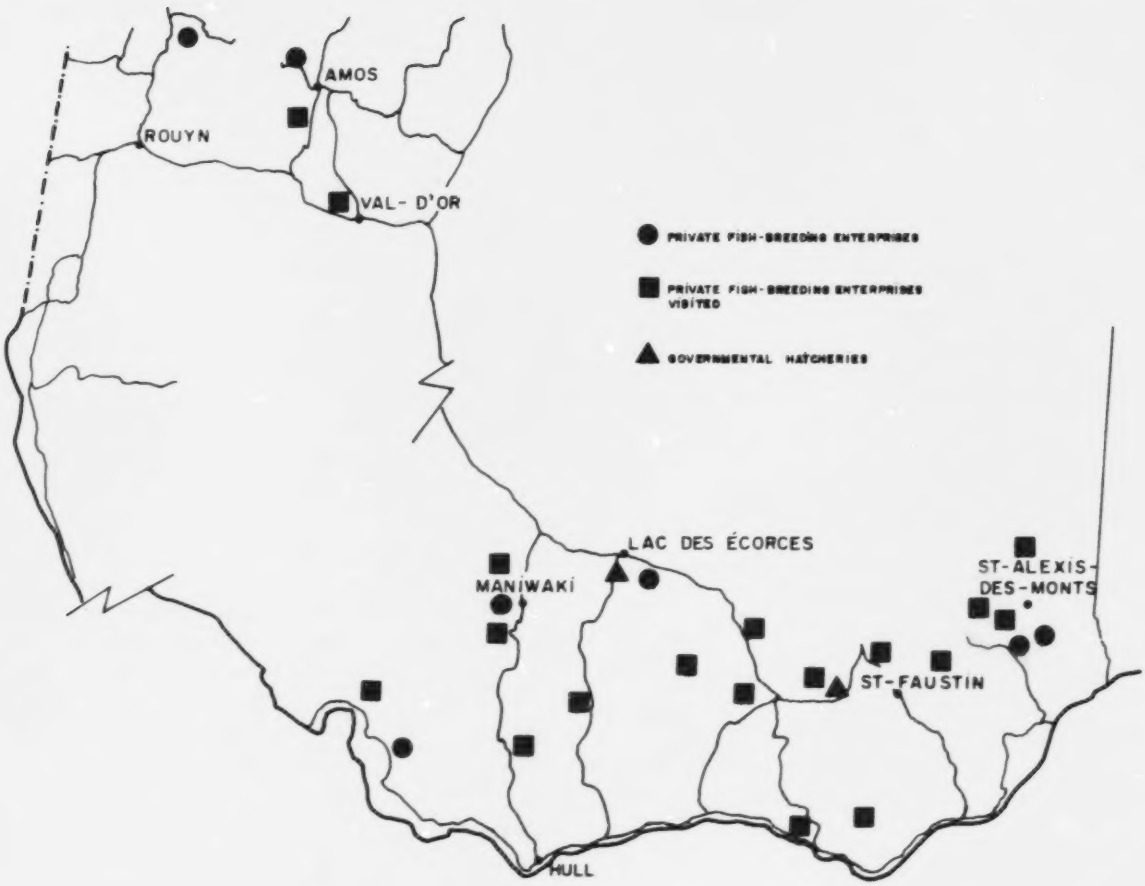

Figure 5. Region I: Northwest Quebec.

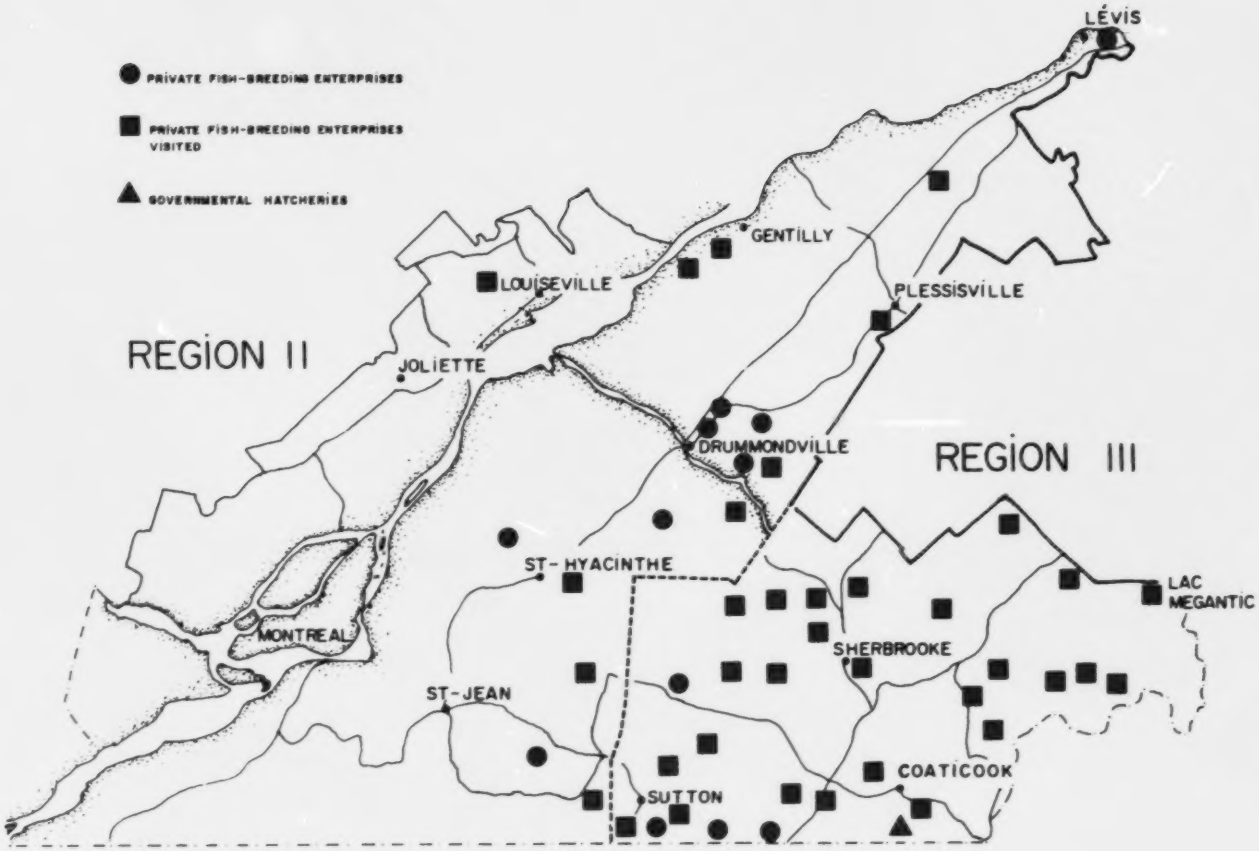

Figure 6. Region II: St.Lawrence Lowlands, and Region III: Eastern Townships.

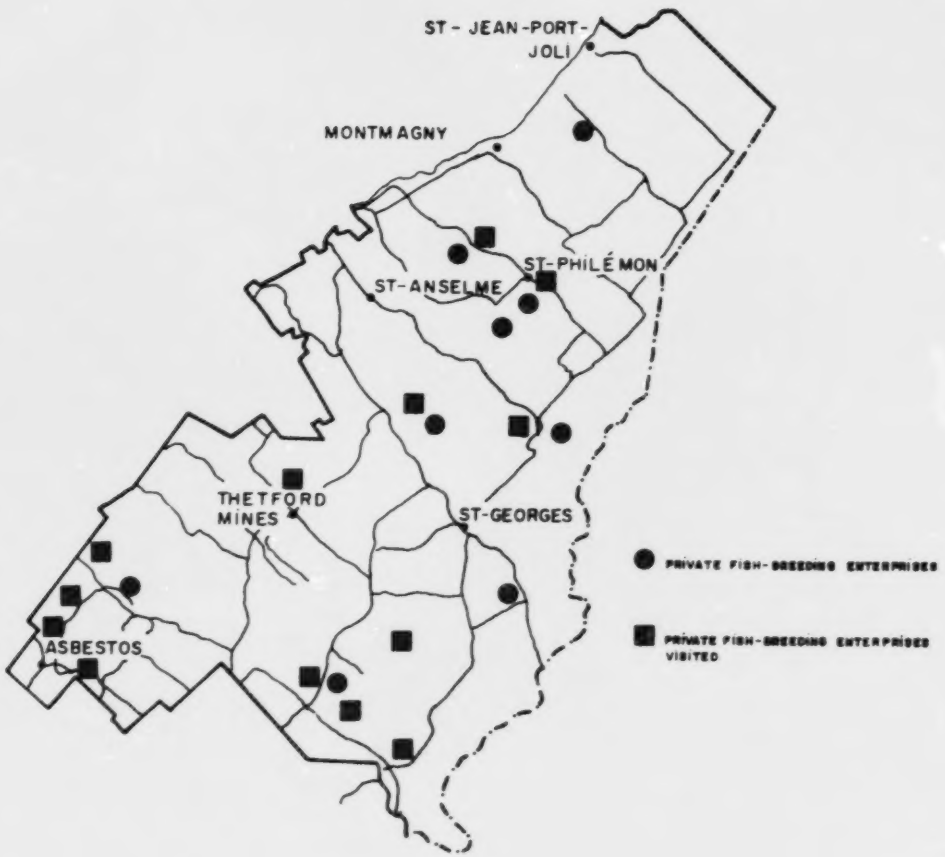

Figure 7. Region IV: Beauce.

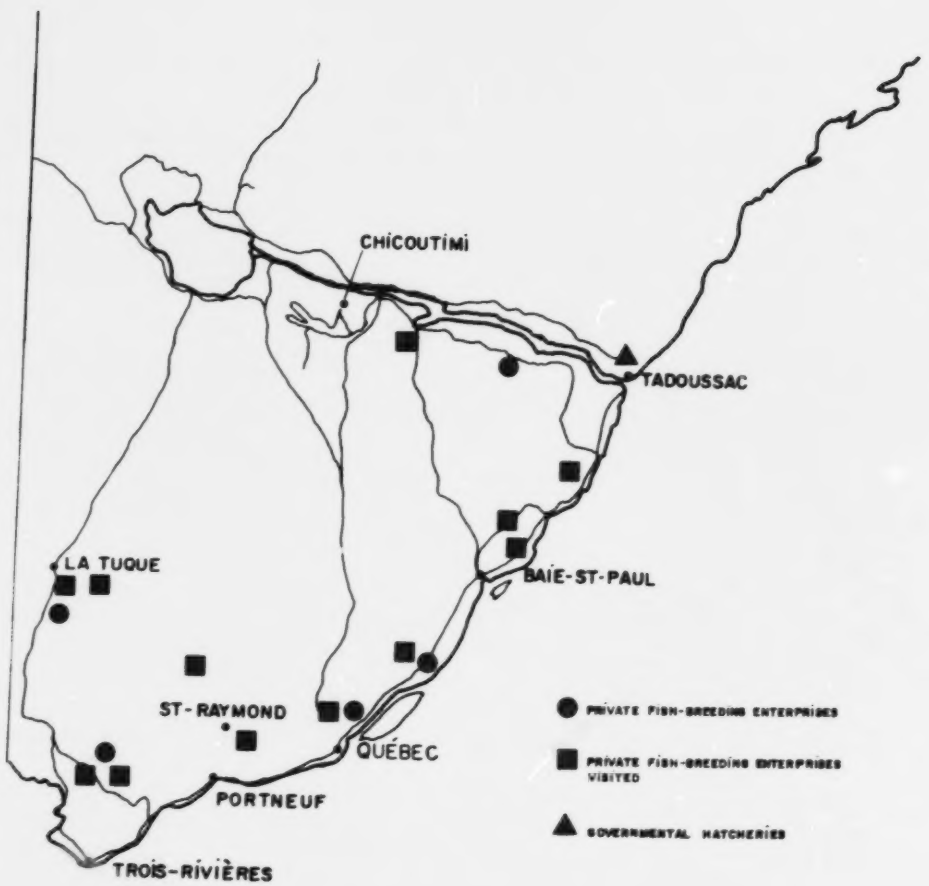

Figure 8. Region V: Northeast Quebec.

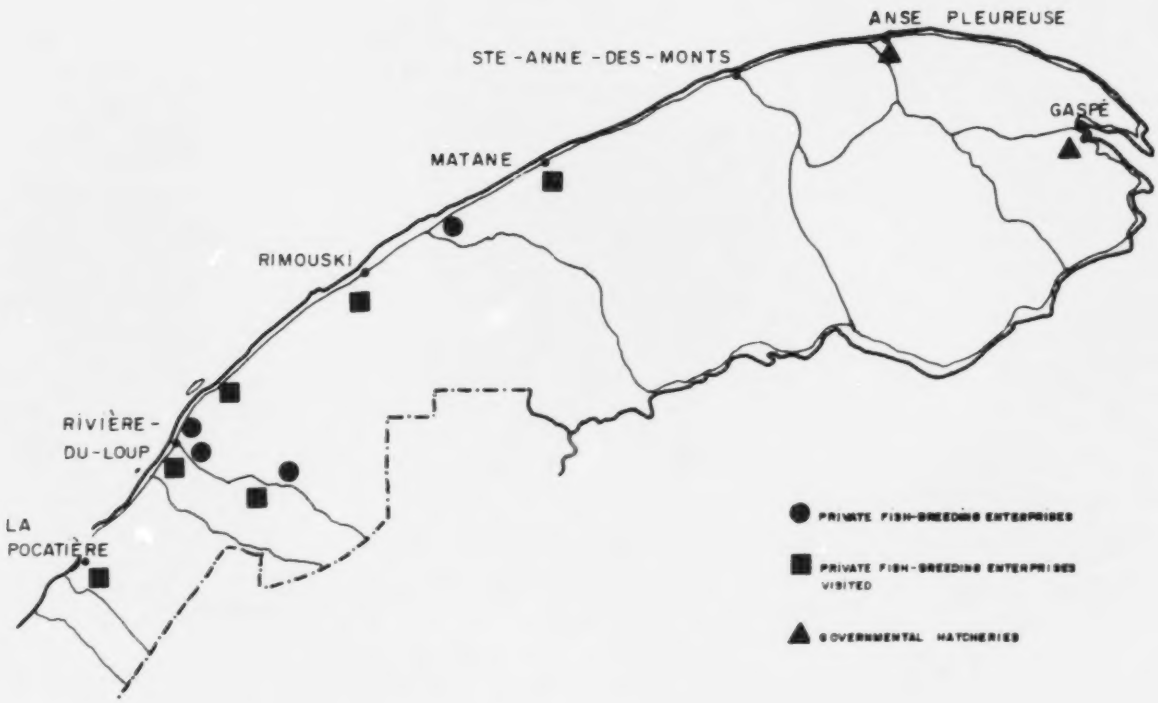

Figure 9. Region VI: Gaspé.

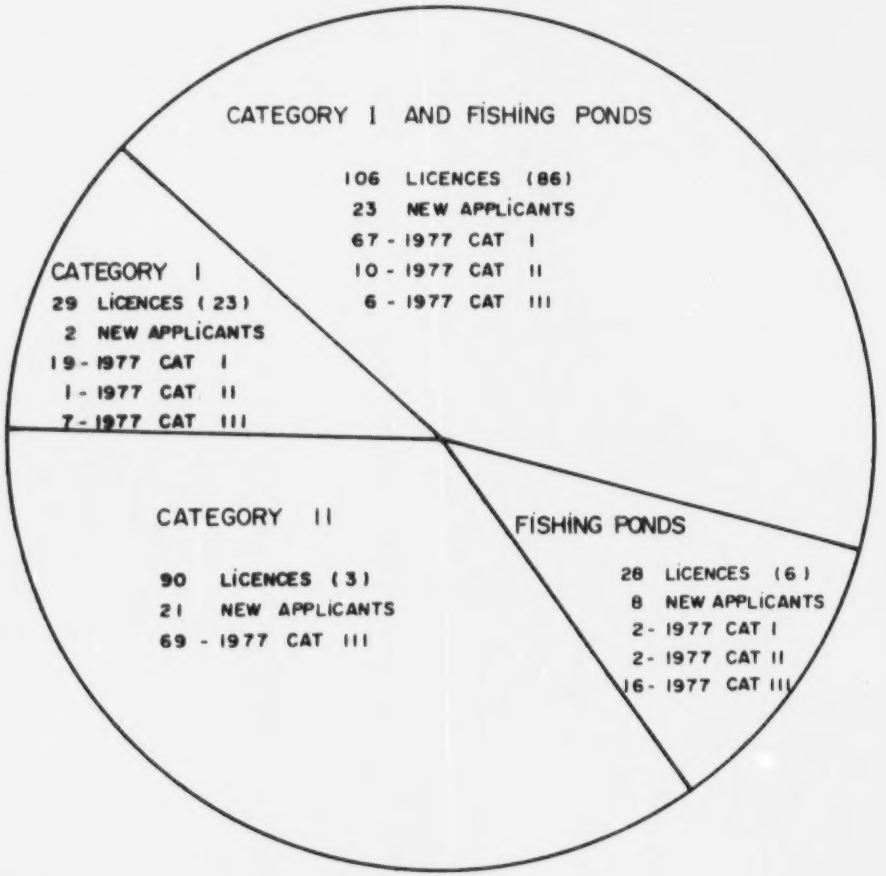

Figure 10. Number of fish-culture licences issued.

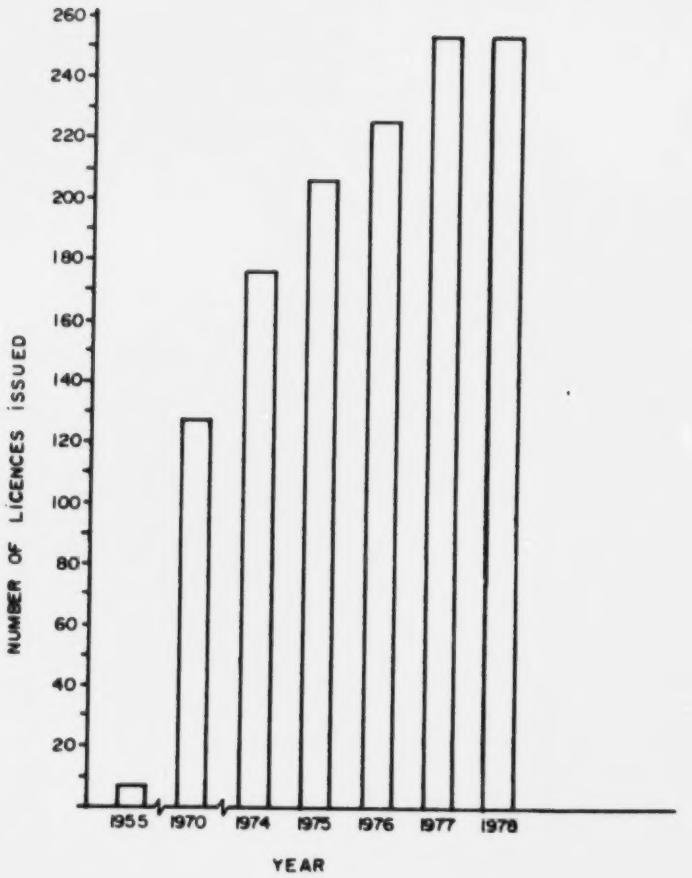

Figure 11. Categories of licences in 1978, showing the adjustment from 1977 categories. Figures in parentheses represent the number of enterprises surveyed.

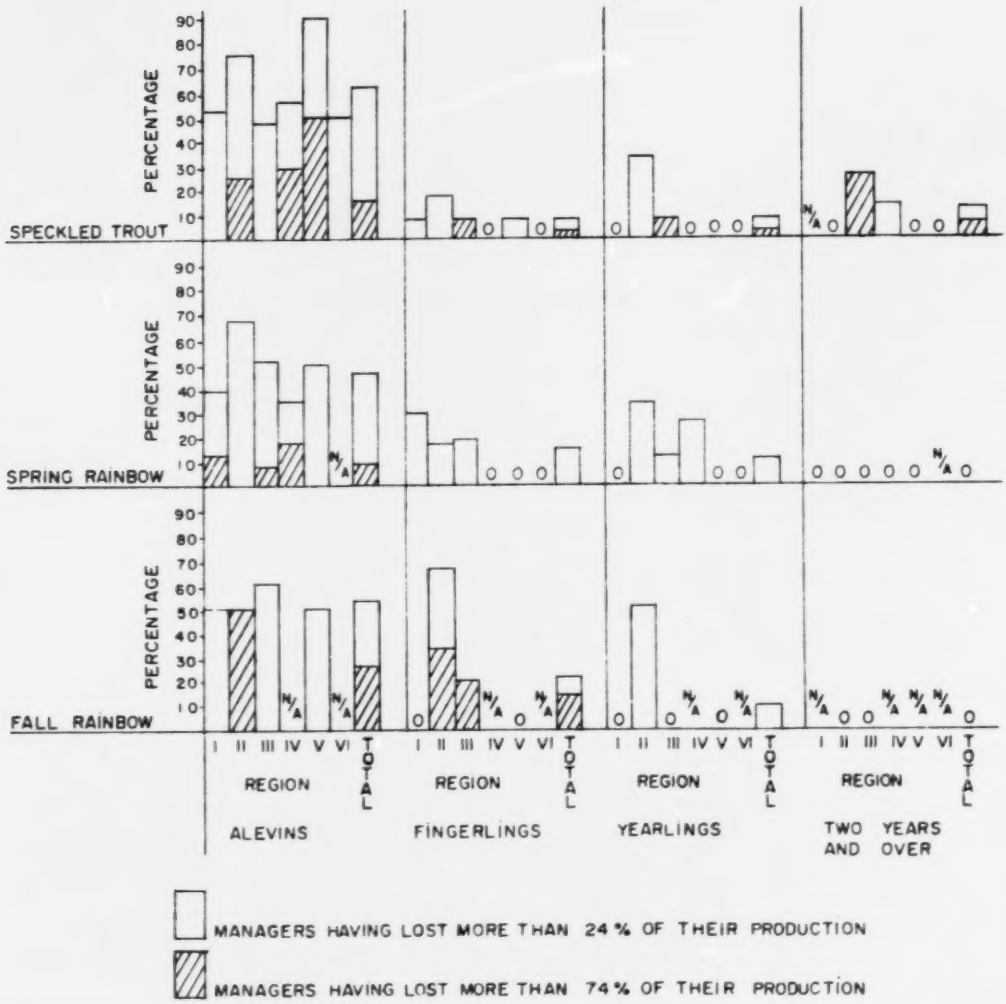

Figure 12. Losses by species, stage of development and region.

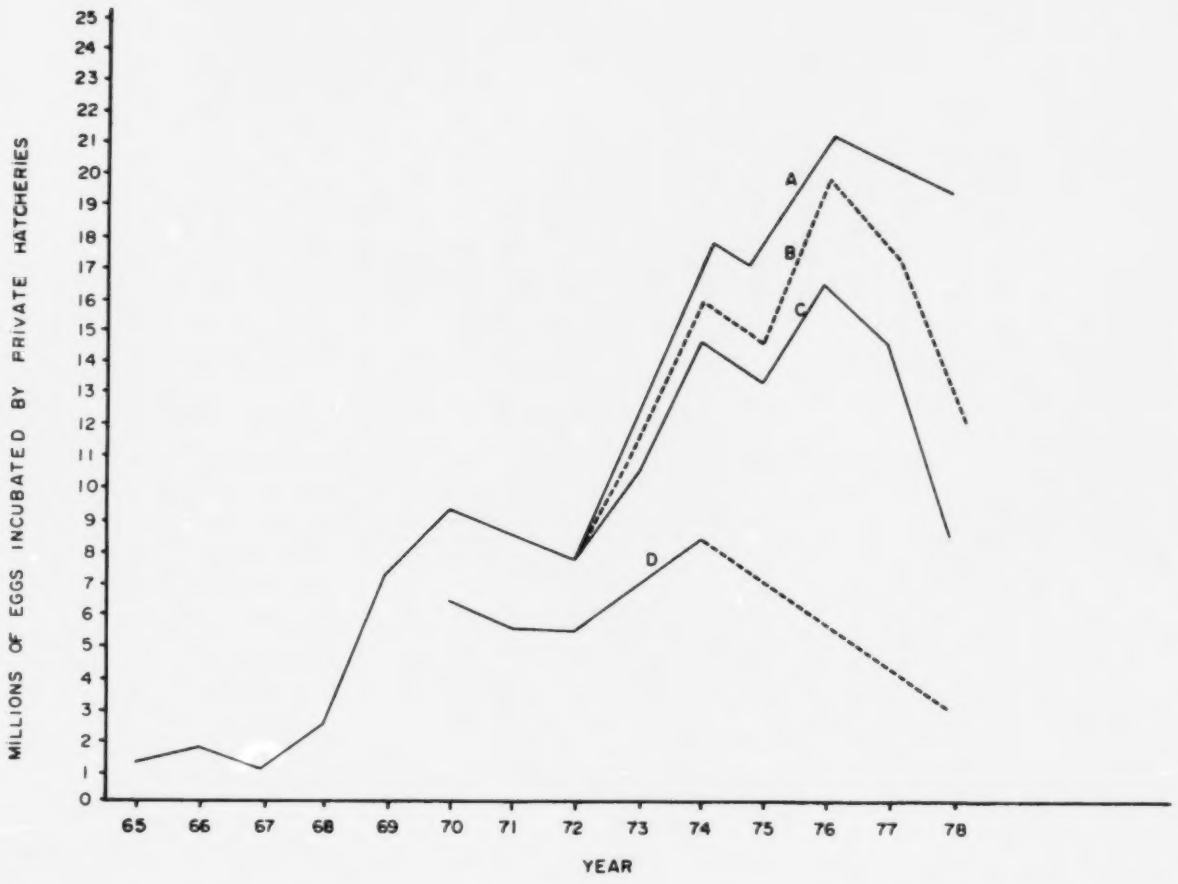

Figure 13. Sales of salmonid eggs to private hatcheries and number of eggs incubated. A = Total incubated. B = Total sales. C = M.L.C.P. sales. D = M.L.C.P. imports Stippled line is an estimate.

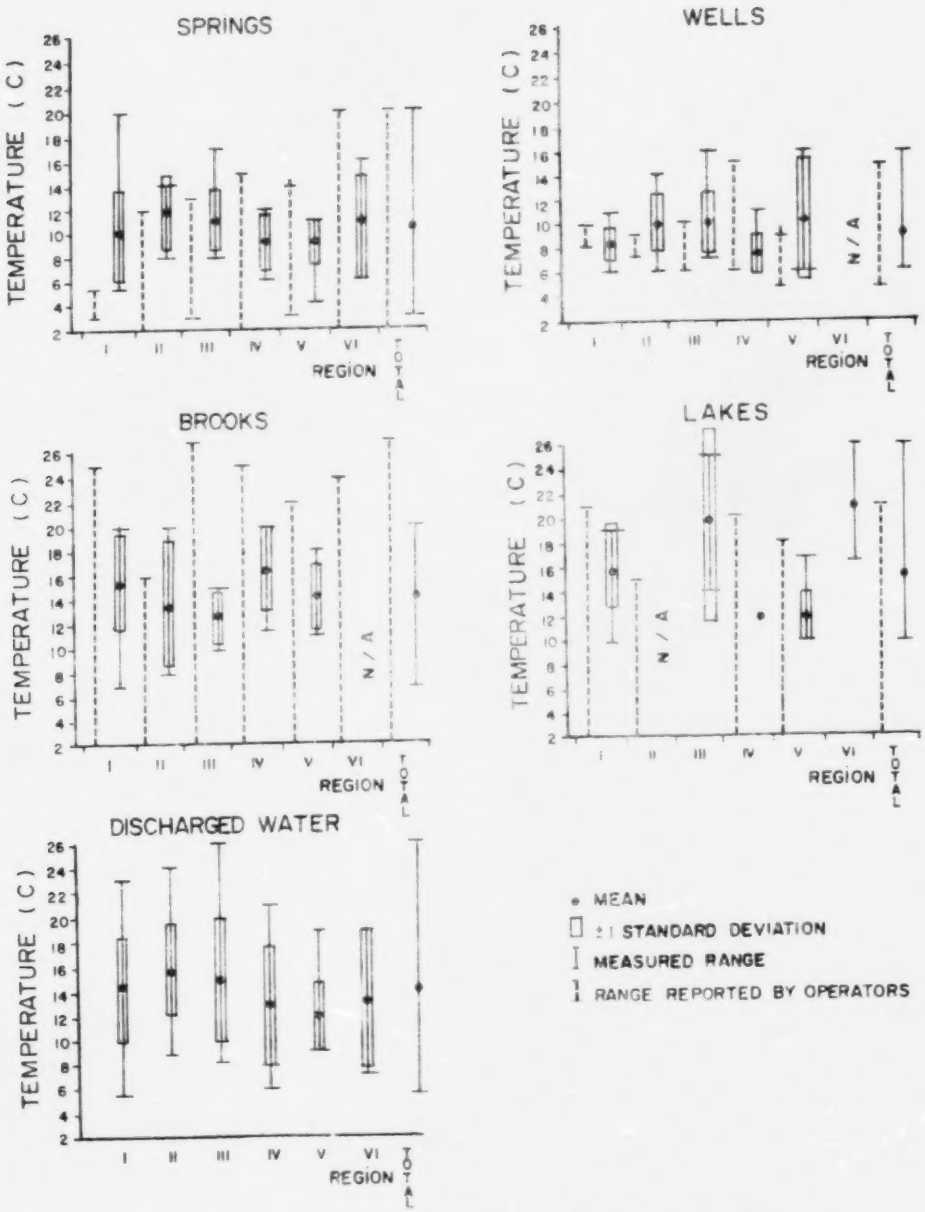

Figure 14. Temperature.

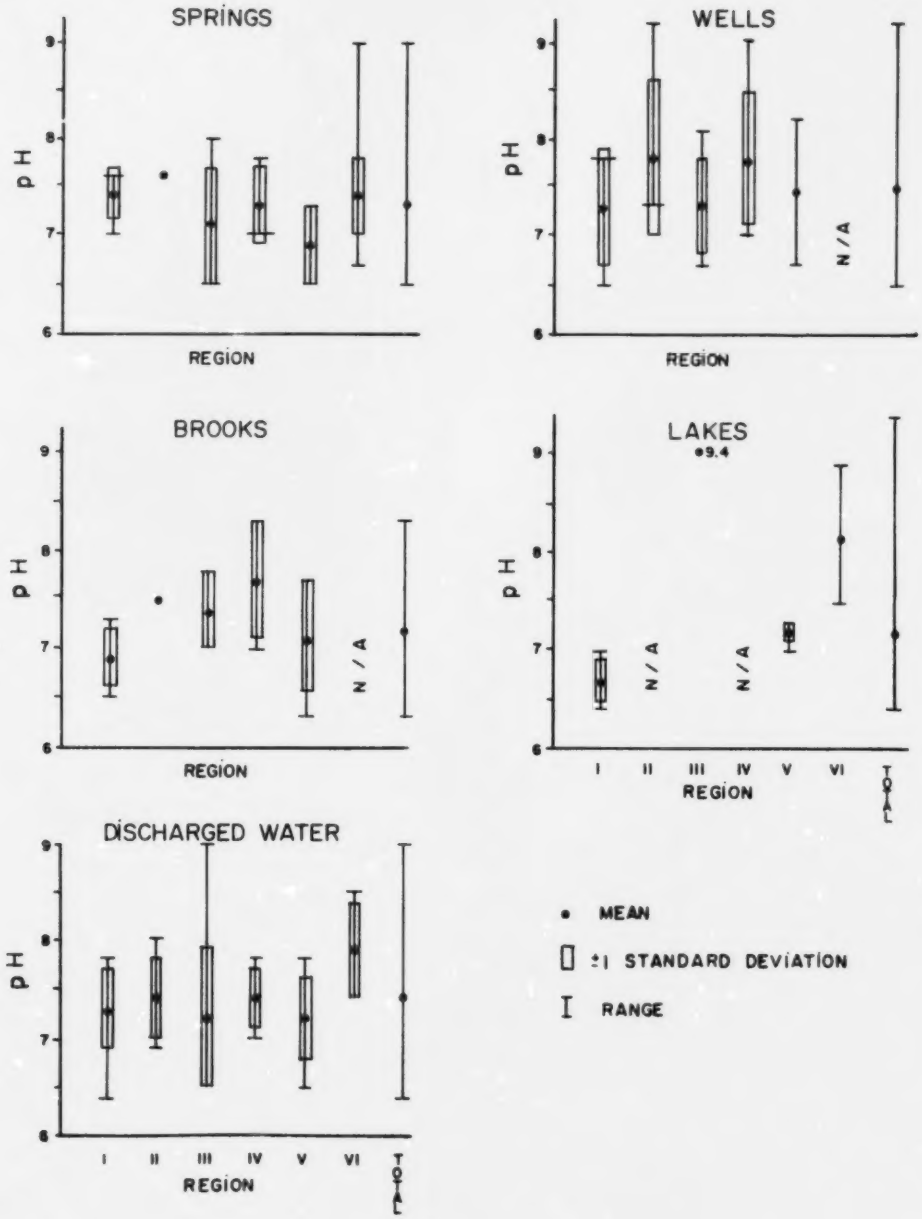
SPRINGS
WELLS
BROOKS
LAKES
•9.4
DISCHARGED WATER
pH
REGION
N/A
I
II
III
IV
V
VI
TOTAL
• MEAN
±1 STANDARD DEVIATION
RANGE

Figure 15. pH.

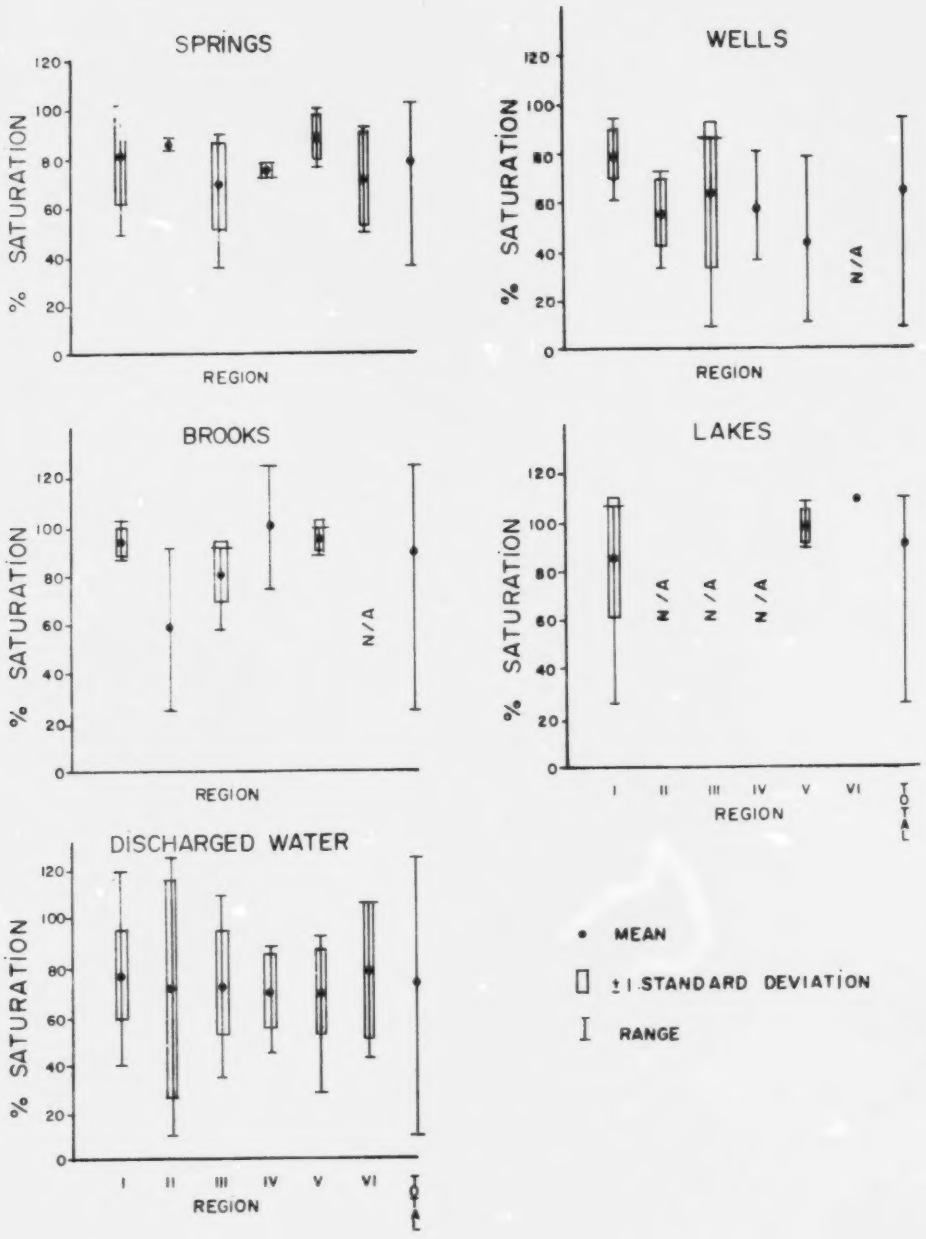

Figure 16. Dissolved oxygen.

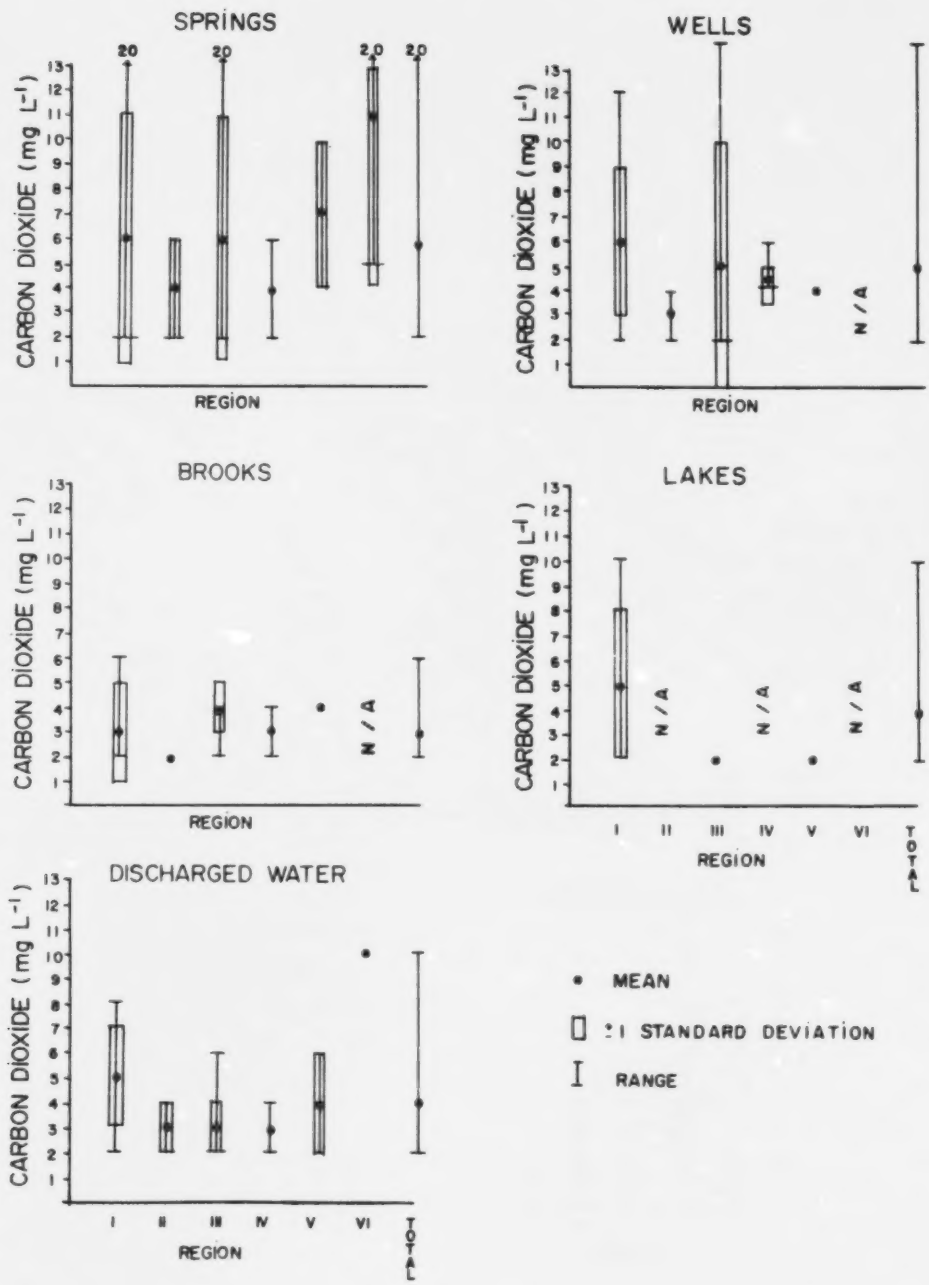

Figure 17. Carbon dioxide.

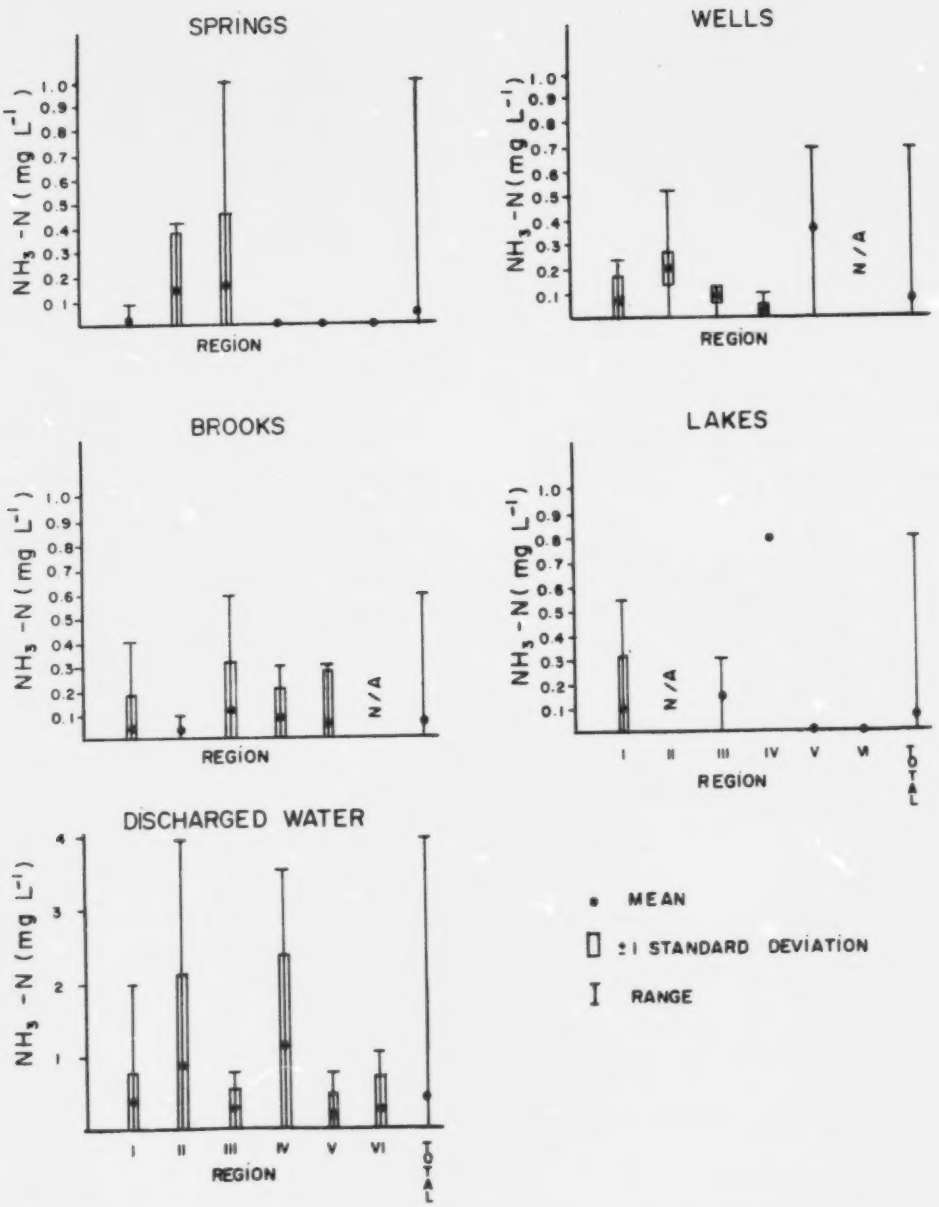

Figure 18. Ammonia nitrogen.

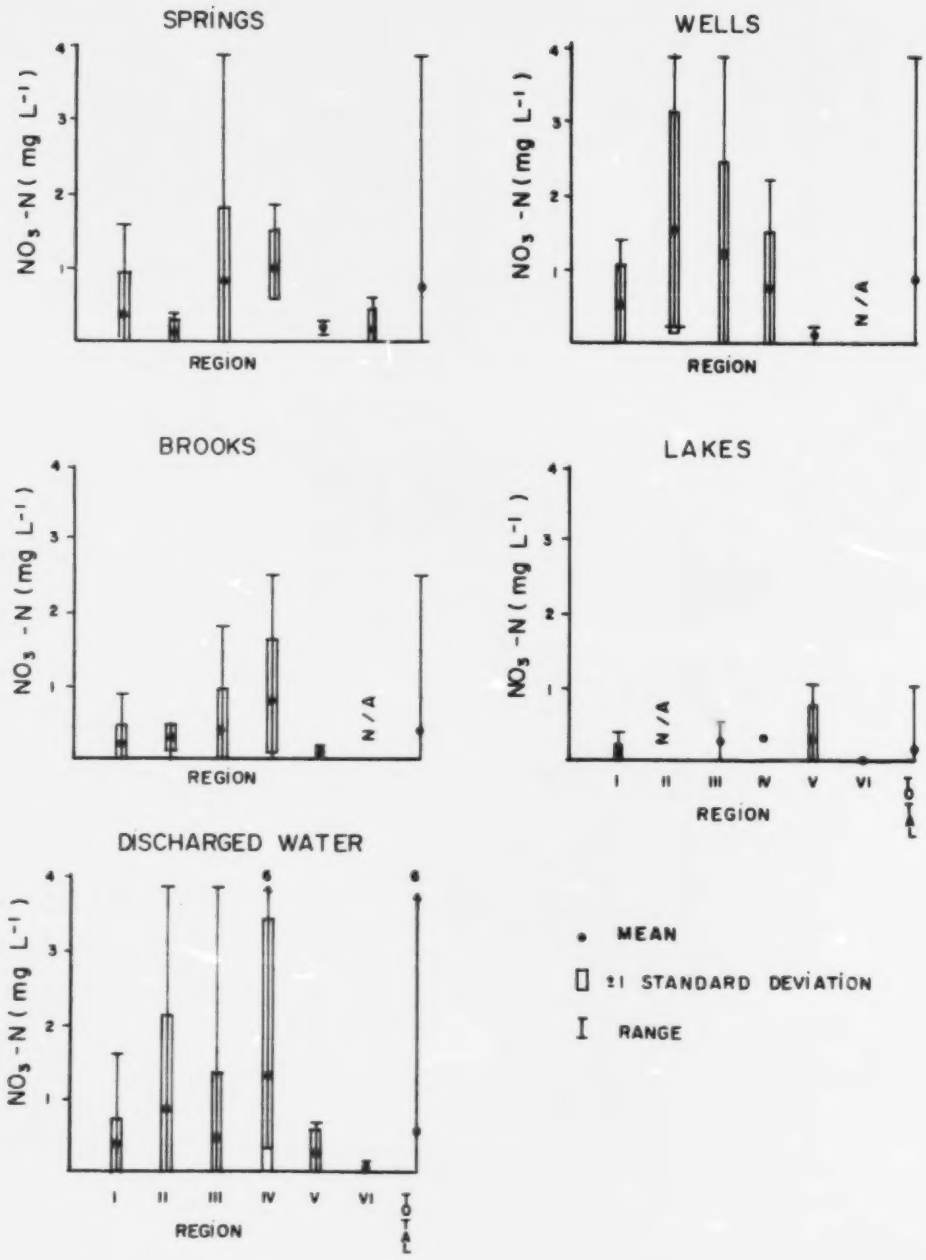

Figure 19. Nitrate nitrogen.

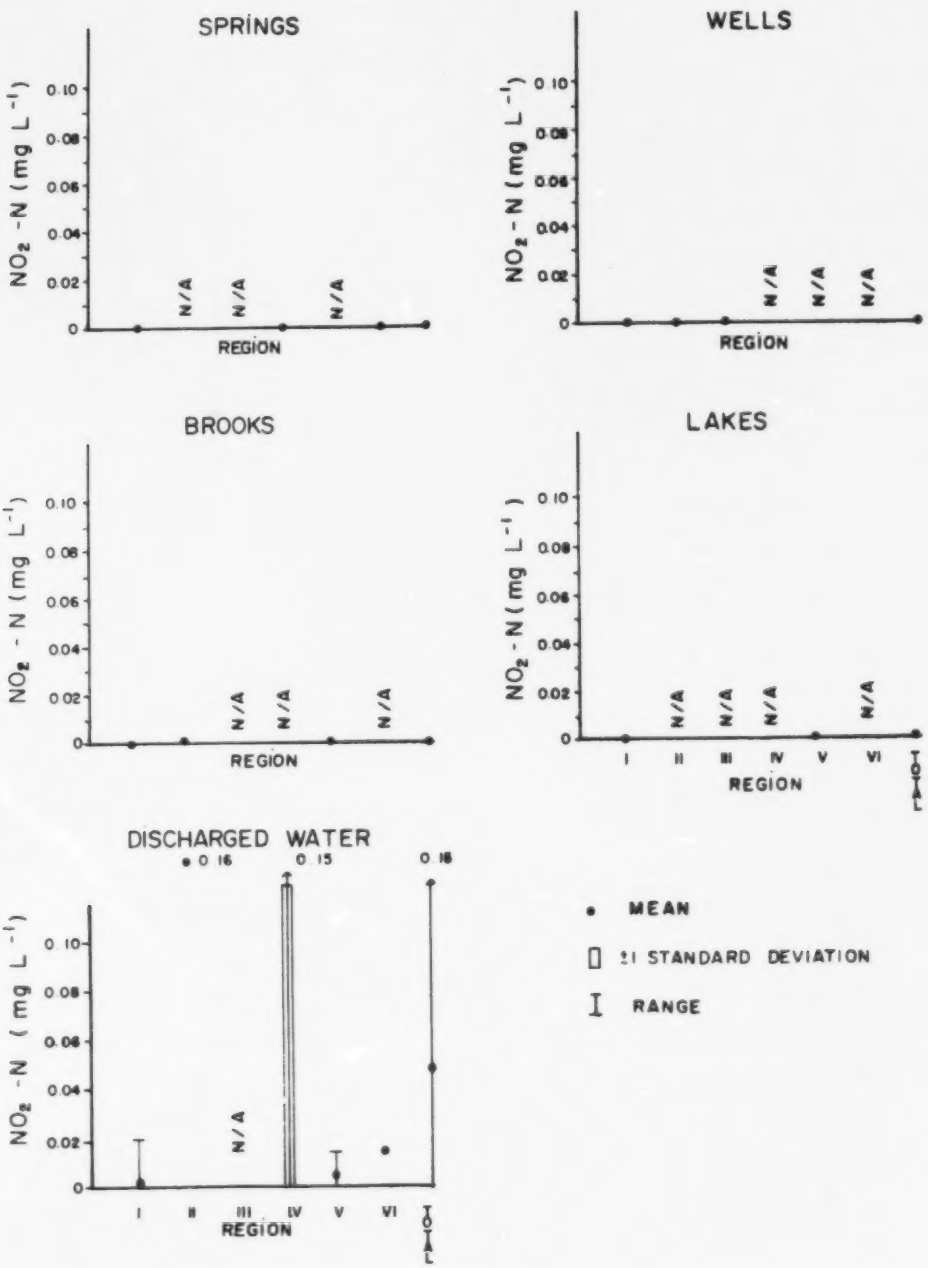

Figure 20. Nitrite nitrogen.

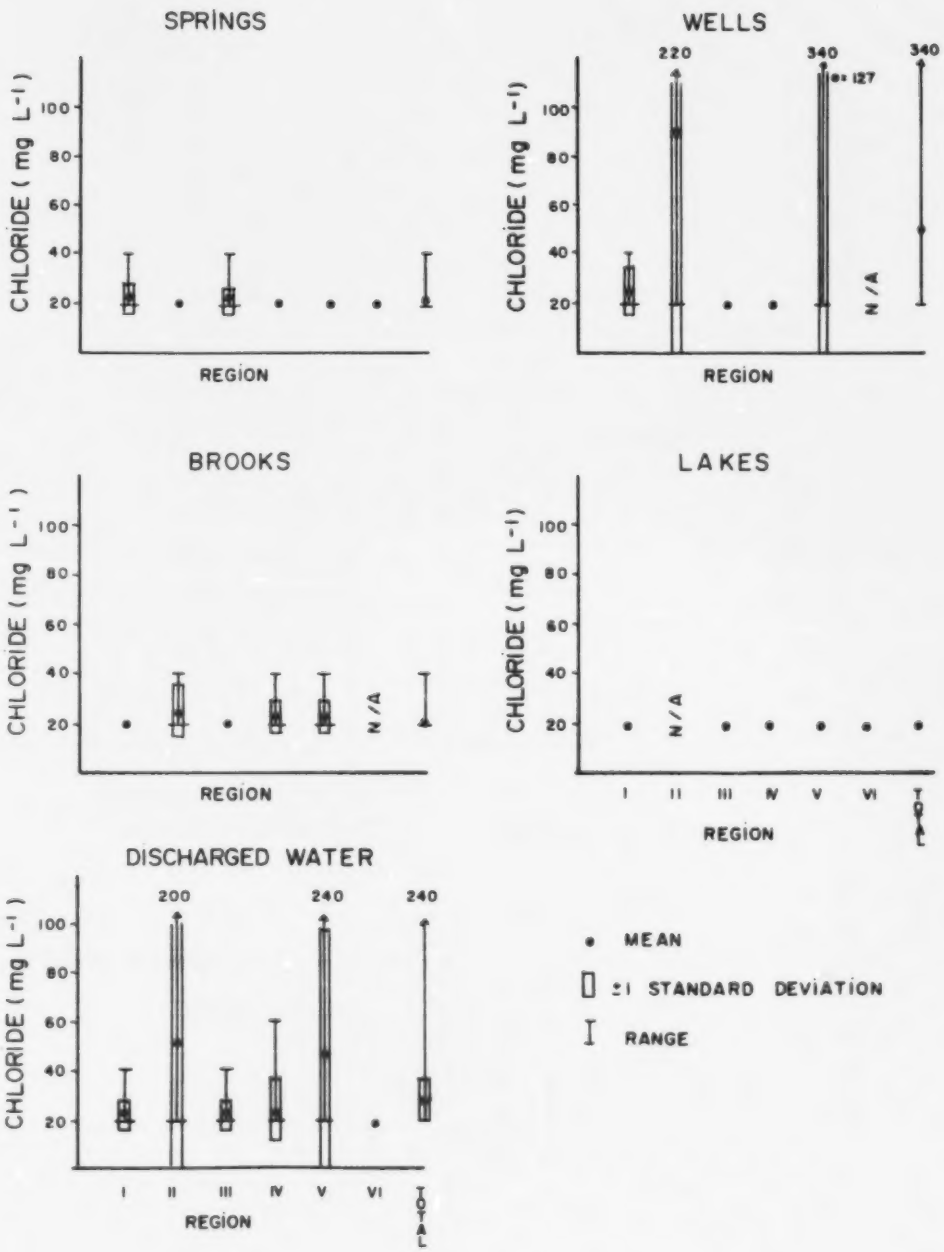

Figure 21. Chloride.

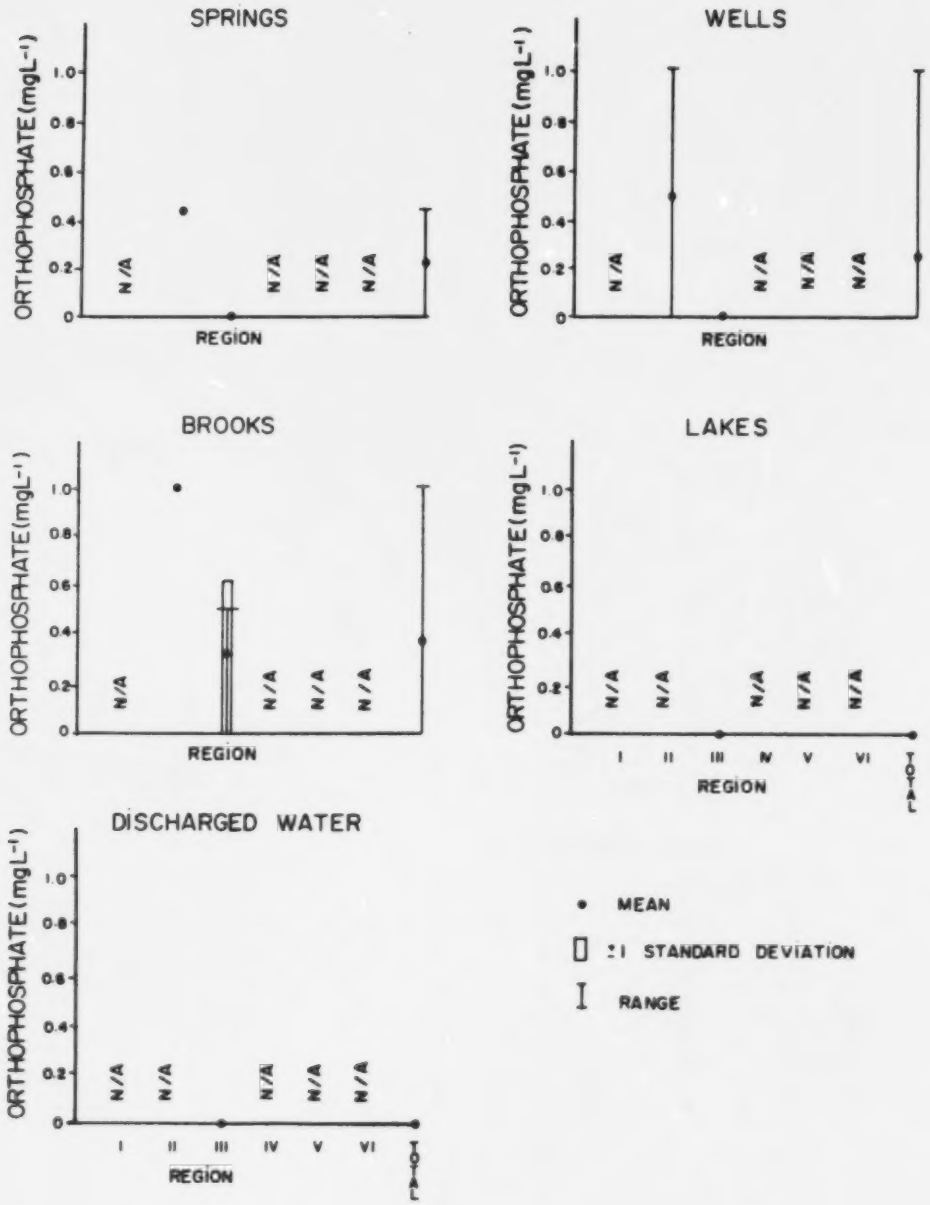

Figure 22. Orthophosphate.

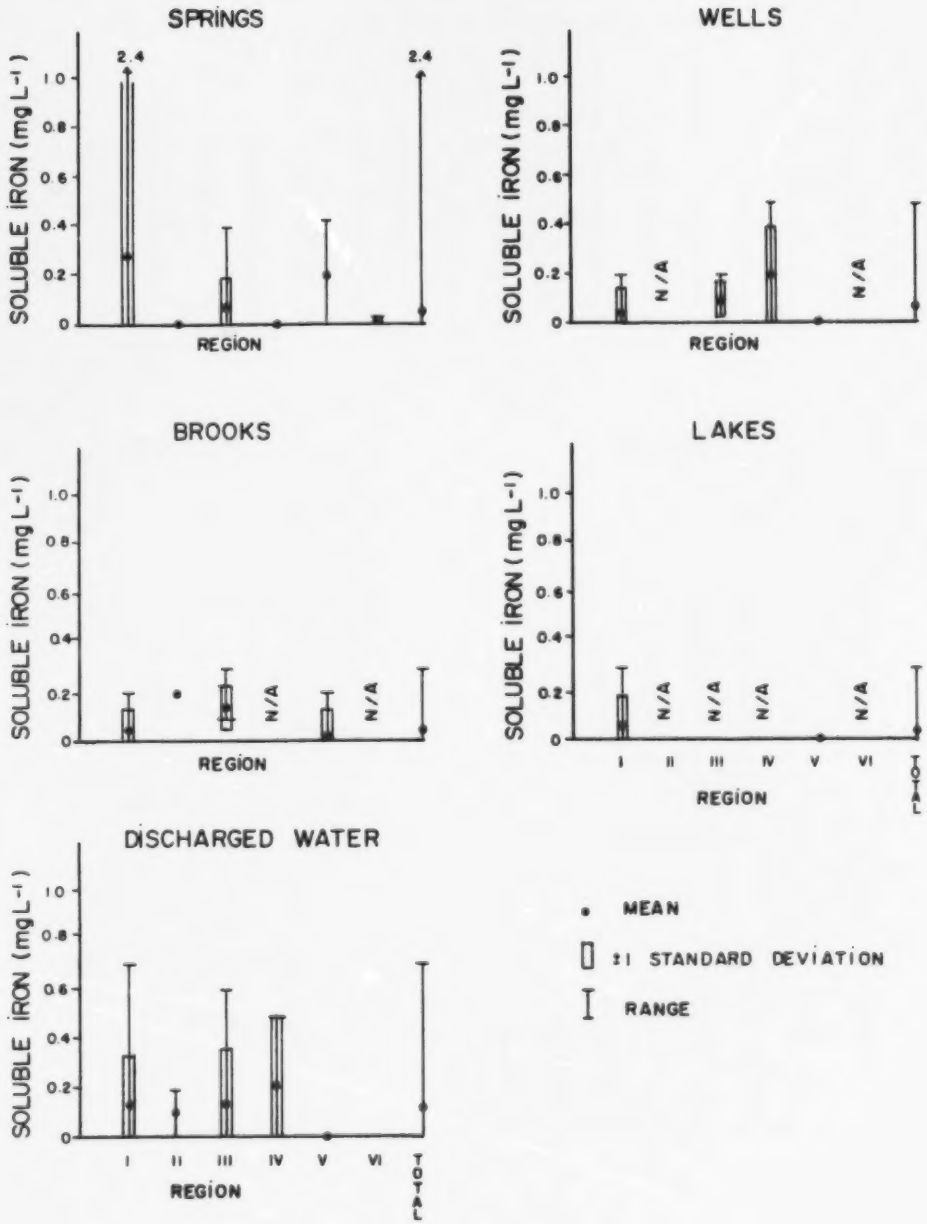

Figure 23. Soluble iron.

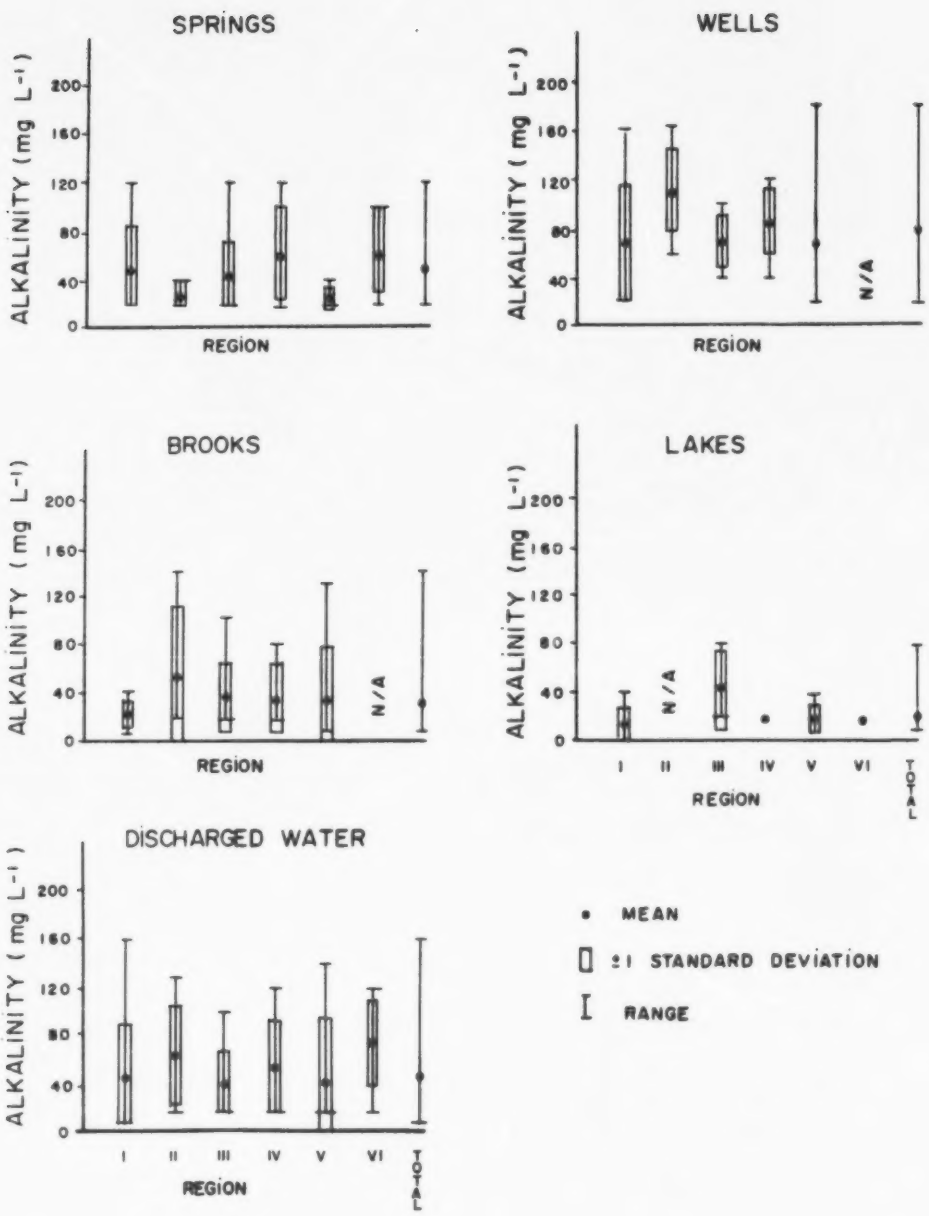

Figure 24. Alkalinity as calcium carbonate.

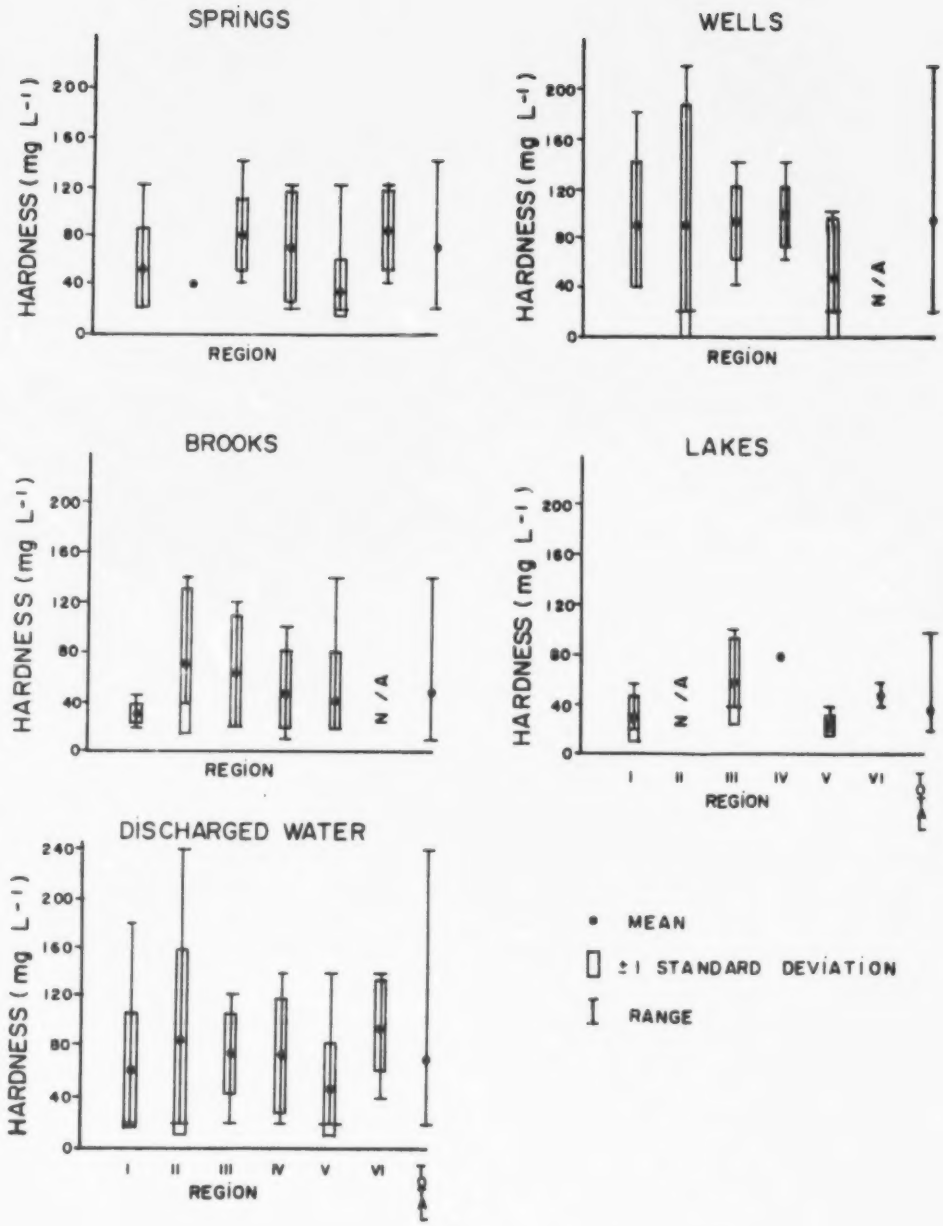

Figure 25. Hardness as calcium carbonate.

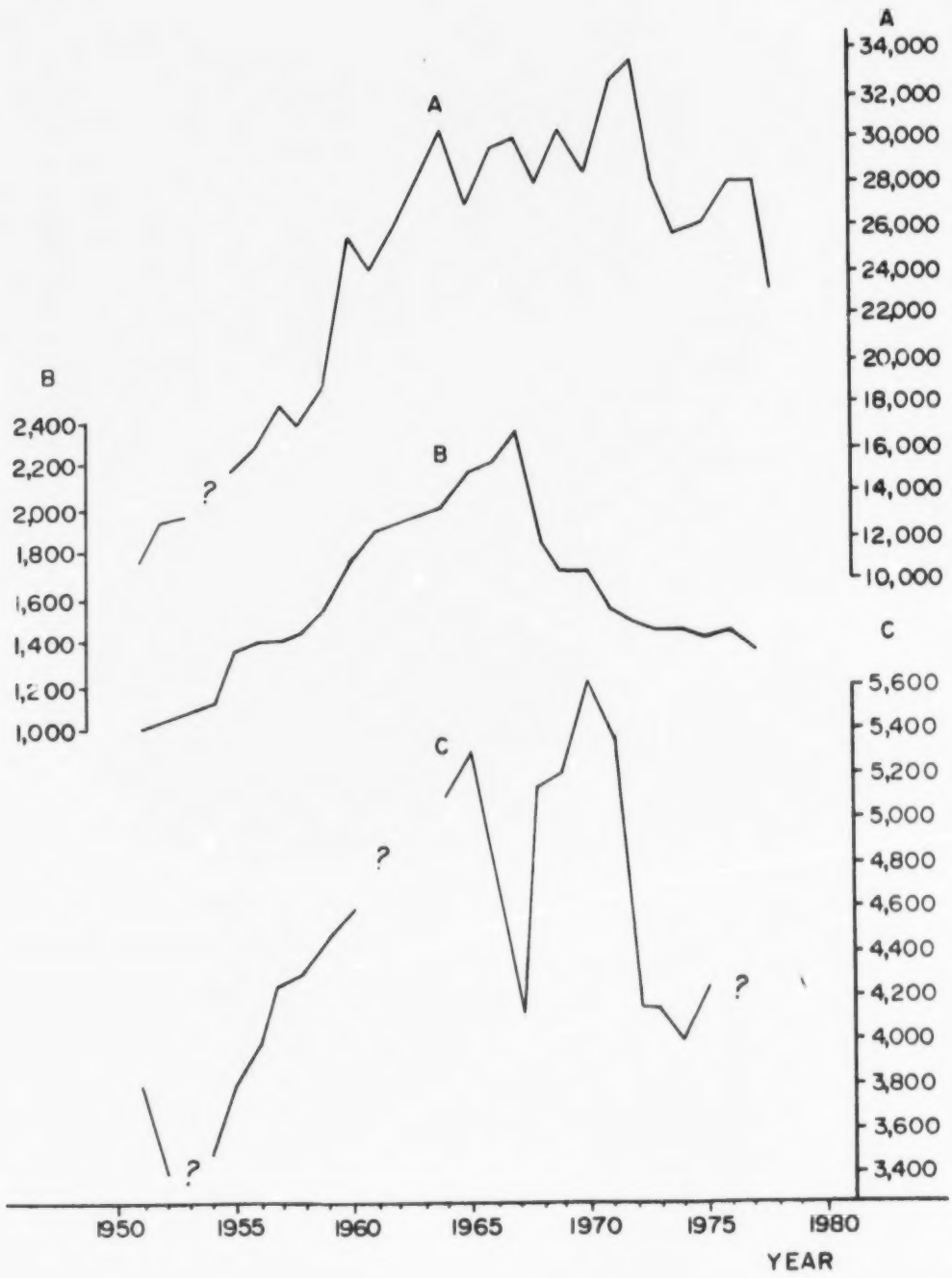

Figure 26. Statistics on private fishing clubs. (A) Membership. (B) Number of leases. (C) Part-time and full-time employees. Source: Annual reports of the Ministère des Loisirs, de la Chasse et de la Pêche (Anonymous 1960-1978).

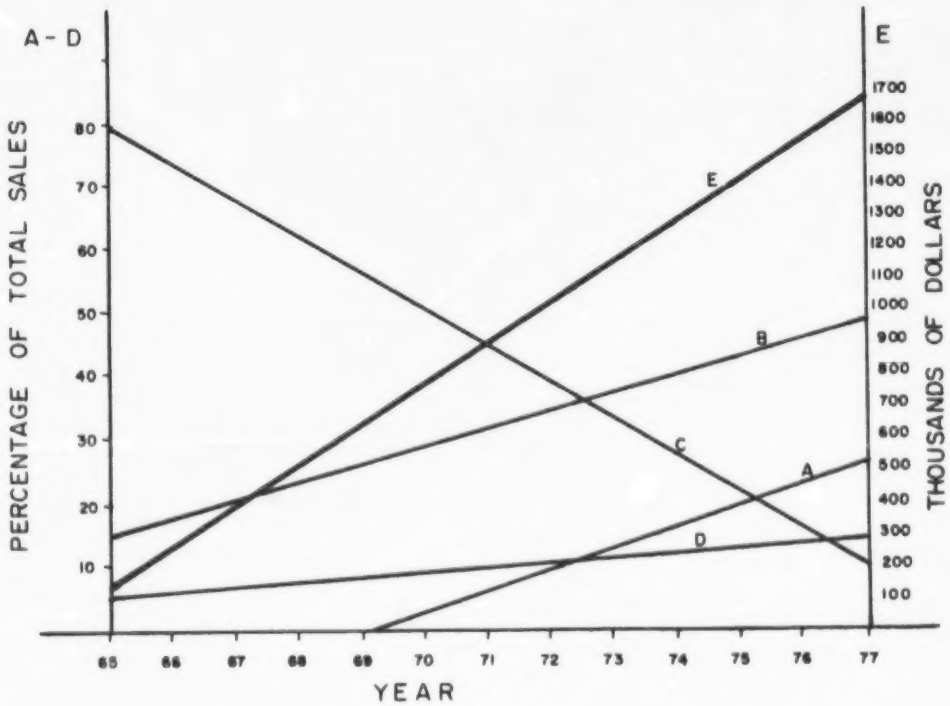

Figure 27. Schematic distribution of annual sales and total value. Curves A to D indicate the percentage of the total annual sales represented by the following sectors: (A) Sales to fishing ponds and retail stores. (B) Sales to private ponds. (C) Sales to private clubs. (D) Sales to other hatcheries. (E) Total value.

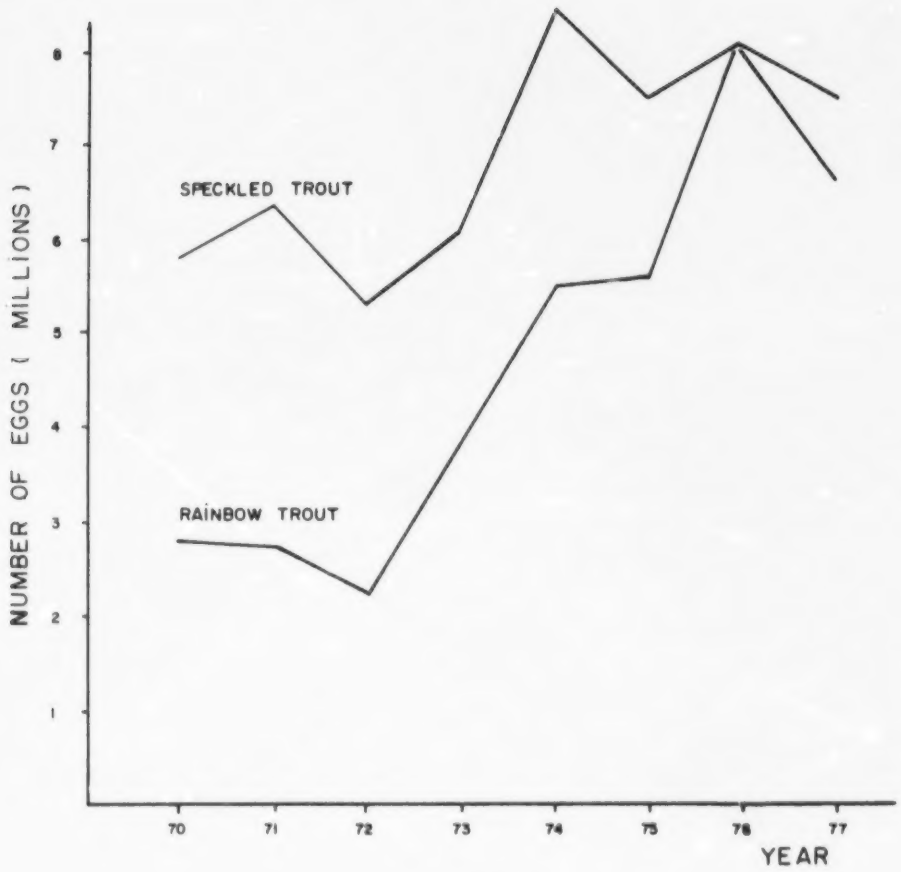

Figure 28. Annual sales of eggs by the Government of Quebec (MLCPQ).

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APPENDIX A: HISTORICAL REVIEW OF INTRODUCTIONS OF EXOTIC SALMONIDS WITHIN QUEBEC

The stocking of exotic salmonids in Quebec is restricted through the Quebec Fishery Regulations and the Fish Health Protection Regulations made under the Fisheries Act of Canada. Importation of salmonids by private parties has been forbidden since 1968 and fish culture subjected to zone restrictions since 1978 (See Appendix B). Previously, there were no restrictions on transportation of fish into and throughout the Province and private as well as governmental hatcheries freely introduced imported eggs and fish. There is reason to believe that the original introductions of rainbow trout (Salmo gairdneri), brown trout (S. trutta) and cutthroat trout (S. clarki) were all private undertakings. However, governmental programs are undoubtably responsible for most of the successful exotic salmonid implantations in Quebec.

In many cases, the introductions were made in order to satisfy the desire of sport fishermen to fish for the exotic species. In some cases, the exotic fish were introduced into waters in which indigenous salmonids were no longer present. Examples of this are the successful stockings of the waters around the Island of Montreal with brown and rainbow trout. Many of the early stockings were also done in order to establish commercial runs of the introduced species, particularly with lake trout (Salvelinus namaycush) and whitefish (Coregonus clupeaformis).

Three species of trout have become established in our waters and various Pacific salmons have sojourned in our Province occasionally since the 1870's.

In 1875, 4 000 chinook salmon (Oncorhynchus tshawytscha) eggs were received at the Tadoussac Hatchery from the McLeod River Hatchery in California by way of Newcastle, Ontario (Wilmot 1876)*. A year earlier, the Newcastle Hatchery had successfully received from California a small number of chinooks sent by S. F. Baird, Commissioner of the United States Fish and Fisheries Commission. The success of this original shipment had led senator D.E. Price, representative of the Province of Quebec, to request that an attempt be made to hatch Pacific salmon at the Tadoussac Hatchery. In 1876, 40,000 additional eggs were received; fish from those two hatches were released in the Escoumins River (Wilmot 1877). The program continued at the Newcastle site until 1881 and in that year and in 1882, a large number of chinooks were stocked in the St.John River, New Brunswick (Anon. 1883). Wilmot (1877, 1878) reported having sighted chinooks near the Newcastle Hatchery. Chinooks were also caught by fishermen in the St.John River in 1884 (Wilmot 1885). However, there were no reports of returns from Quebec and no populations became established following those early attempts.

In 1890, 100 to 150 thousand sockeye salmon (O. nerka) eggs from the Fraser River were incubated at the Ottawa Fish Hatchery. The following year, these young sockeyes were stocked, along with Atlantic salmon (Salmo salar), in Lakes Meache (84,000), Knowlton (14,000), Smallions (14,000) and Brown** (Wilmot 1891).

* See the list of references to literature following the report.

** Brome?

Nothing else is known concerning those introductions other than that the populations did not persist. Prince (1906) reported that the director of the Baldwin Mills rearing ponds had successfully reared "Pacific salmon", but no other information is given.

There are no other reported stockings of Pacific salmon in Quebec until 1968 when the Government of Quebec stocked 40,000 kokanees (O. nerka) in Laviolette County. No information is available as to their success or failure.

In recent years, Pacific salmon have been found in Quebec waters. In 1967, a pink salmon (O. gorbuscha) was gill-netted near Mutton Bay and another was found dead in Watchichou River. Both sites are in the Quebec North Shore region and the fish were presumed from Newfoundland releases (Lear 1975; Legendre and Carter 1978). During the 1970's cohos (O. kisutch) have been caught by sport fishermen in the St. Lawrence River near Montreal (Gruenefeld 1977; Nadeau et al. 1974). No doubt these fish were from releases made in the Great Lakes in the late 60's and early 70's by New York State or Ontario fish hatcheries.

Little is known concerning the early introductions of rainbow trout into eastern Canada. The Fish Breeding Division of the Canadian Government directed its early efforts towards improving the commercial fisheries. It did not pay any attention to rainbow trout which it considered as a sport fish. The neighbouring states were stocked early: New York in 1874, New Hampshire in 1878, Vermont in 1880 and Maine in 1882 (MacCrimmon 1971). In Ontario, rainbow trout were first brought in by a private individual in 1881 and by the Ontario Government in 1883 (MacCrimmon 1971). Wilmot (1889) describes the experimental stocking of a pond with fingerlings at the Newcastle Hatchery in 1888. The superintendent requested that a supply of eggs be sent the following year, but none are known to have been procured.

The United States Fish Commission reported the sale of 10,000 rainbow eggs to a W.P. Greenough of Portneuf, Quebec (Bean 1896). This is the first documented introduction of rainbow trout into Quebec. However, nothing is known about the fate of the fish, if indeed the eggs were successfully hatched.

It was not until 1903 and 1904 that federal authorities stocked rainbow trout in Quebec. In those years the Ottawa Hatchery stocked several lakes in the Ottawa River valley and the Laurentians (Prince 1904, 1905). In 1910, the St-Alexis-des-Monts Hatchery hatched 50,000 rainbow eggs. The eggs came from New York State; fish were stocked in Lakes Carolus, Ferron and La Hêche, in the vicinity of St-Alexis-des-Monts, in 1912. In that same year, the Ottawa Hatchery sent 10,000 eyed eggs to Lake Meache (Rodd 1913). Taylor reported that by 1932 rainbow had been cultured for over twenty years. He also confirmed that there were several established populations in Eastern Townships waters (Taylor 1932).

As is the case of rainbow trout, there is little information on the early introductions of brown trout into eastern waters. Stocking programs were initiated in New York in 1883, Maine in 1885, New Hampshire in 1887 and Vermont in 1890. Brown trout was also introduced in Newfoundland as early as 1886 (Andrew 1965) or perhaps 1884 (Catt 1950). Ontario provincial authorities initiated a program in 1913 (MacCrimmon and Marshall 1968). In Quebec, P.C. Nobbs reported that brown trout were stocked in the North River, Terrebonne County, in 1890 (Samson et al. 1976). That same year, there was also a stocking in Lac Brûlé, Quebec (Catt 1950). Lastly, the 1896 report by Prince suggests he was familiar with brown trout (Prince 1906). See Table 2 for more information on provincial stockings of rainbow and brown trout.

There are reasons to believe that exotic species, particularly brown trout and rainbow trout, were stocked more extensively than would be inferred from this scant information. There is evidence that as early as the 1850's individuals were importing fishes from Europe. In 1857, R. Nettle made an unsuccessful attempt to import Atlantic salmon eggs from the River Moy in Ireland. Prince (1905) reports that S. Wilmot received from England in 1870 a small quantity of "Salmo umbla" (Salvelinus alpinus). In 1877, another 200 "Salmo umbla" eggs were hatched at the Newcastle Hatchery (Wilmot 1878).

The policy of leasing public lands and fishing rights no doubt stimulated the establishment of small private fish hatcheries. Bowen (1970) states that there were in 1870 over a hundred people practicing fish culture in the U.S.A. J. Holliday and his family periodically ran a breeding facility on the Moisie River from 1859 till 1912 in order to enhance the resource (Chambers 1912). Similarly, the Baldwins Mills Rearing Ponds (Taylor 1942) and the St-Alexis-des-Monts Hatchery (Chambers 1922) were both originally established by private individuals. Prince (1905) states that there were more than five private fish hatcheries operating in Canada by the turn of the century. Keeping this in mind, it can be supposed that private parties may well have stocked waters with exotic species even if such introductions were not officially recorded.

More recently, cutthroat trout and Danube salmon (Hucho hucho) were introduced in Quebec, in 1942 and 1967 respectively. The cutthroat trout were apparently escapees from a private hatchery in Maskinonge County (Samson et al. 1976). They were also raised by provincial authorities in the early 1970's. Danube salmon were imported from Czechoslovakia under the auspices of V.D. Vladykov (Paulhus 1970b). Fish were planted along the St. Lawrence and Ottawa Rivers the following year. A brood stock was maintained at the Baldwins Mills Hatchery for several years and there have been small plantings from that stock in the 1970's. Apparently, the cutthroat have become successfully established; however, there have been no reports of the capture of Danube salmon in the St. Lawrence or elsewhere.

Fish other than salmonids were also introduced. Indeed the most successful and controversial of all introductions is, without a doubt, that of the European carp (Cyprinus carpio). The carp does not appear to ever have been intentionally stocked in Quebec and its appearance in the Province seems to have been through invasion from neighbouring waters: the St. Lawrence River (circa 1900) and Lake Champlain (1883) (MacCrimmon 1968). MacCrimmon (1968) mentions "Les poissons de nos eaux" (Melançon 1936) as the first reference to carp in Quebec; however, Richardson (1935a)

reports that C. carpio and C. cyprinus were collected in the Montreal area as early as 1869. J. Ferrier of Montreal was known to keep goldfish (Carassius auratus) in an aquarium as early as 1859 (Chambers 1912); this does offer some credibility to these sightings. If those fish were present in the area during that time interval, their low numbers or the fact they were of no commercial interest may account for the time lapse until the next reporting.

Most of Canada's indigenous species which have been cultured have probably had their ranges extended through the stocking of lakes in which they were originally absent. Great lakes whitefish and lake trout were being widely stocked in Quebec in the early 1880's. Similarly, smallmouth bass fry and to a lesser extent ouananiche had their range enlarged through stockings and transplants by fishermen (Prévost 1949). The actual extension of most of these fish ranges is not clear as their original distribution is not known. For a more exhaustive list of fish species cultured in Quebec, see Table 1.

APPENDIX B: FEDERAL AND PROVINCIAL REGULATIONS RELATING TO AQUACULTURE IN QUEBEC

FISH HEALTH PROTECTION REGULATIONS

The Department of Fisheries and Oceans (Canada) is responsible for the application of the Fish Health Protection Regulations, made under the Fisheries Act of Canada. The Regulations aim at preventing the introduction and the spread of disease agents in Canada. They apply to fish, live or dead, and fish eggs moving into or throughout Canada. Disease free establishments are issued a certificate. This certificate along with a permit are required to import cultured fish or eggs of wild fish into any province.

QUEBEC FISHERY REGULATIONS

The Quebec Fishery Regulations, made under the Fisheries Act of Canada, entitles the Province of Quebec (MLCPQ) to control the importation and exportation of live eggs and live and dead fish. Permits are issued to control the transportation or transfer of live fish and fish eggs intended to be hatched, the collection of fish for breeding or restocking, and the extraction of fish eggs for breeding. Licences are also required to operate fish-culture establishments. Quebec determines the categories of licences to be issued and establishes the boundaries of fish rearing, transport and introduction zones. Recently, an agreement was reached between the ministers of Agriculture, Pêcheries et Alimentation, and Loisirs, Chasse et Pêche to share those responsibilities (Appendix C). The MLCPQ is also responsible for the administration of the Fish Health Protection Regulations in Quebec.

WATERCOURSES ACT

The Watercourses Act (Ministère de l'Energie et des Ressources, Québec) requires that people wishing to undertake the erection of a work serving to retain the waters of a lake, pond, river or stream, obtain the prior approval of their plans and specifications.

WILDLIFE CONSERVATION ACT

The Wildlife Conservation Act deals with the establishment of piscicultural establishments by the Government of Quebec (MLCPQ).

OTHER REGULATIONS

The Ministère de l'Environnement du Québec is responsible for setting standard relating to piscicultural establishments and man-made ponds. This agency is concerned with such matters as the selection of the site, level control structures, measures to prevent erosion, drainage, and waste disposal procedures, and use of chemicals and antibiotics.

Pisciculturists must also take into account municipal bylaws concerning zonation and construction.

APPENDIX C: PROTOCOLE D'ENTENTE ENTRE LES MINISTERES DE L'AGRICULTURE DU QUEBEC ET DU TOURISME, DE LA CHASSE ET DE LA PECHE SUR LA PISCICULTURE

Les ministres de l'Agriculture du Québec et du Tourisme, de la Chasse et de la Pêche reconnaissant la nécessité de déterminer leurs tâches respectives vis-à-vis la pisciculture déclarent adopter le protocole d'entente suivant:

1) Le ministre du Tourisme, de la Chasse et de la Pêche reconnaît que dans le cas de la pisciculture privée, les aspects production ou élevage de même que le financement ou l'assistance technique et la commercialisation pour la consommation sont maintenant sous la responsabilité du ministre de l'Agriculture;

2) le ministre du Tourisme, de la Chasse et de la Pêche demeure le seul maître d'oeuvre dans le cas des pisciculture gouvernementales;

3) le ministre de l'Agriculture reconnaît la juridiction du ministère du Tourisme, de la Chasse et de la Pêche dans: a) l'émission des permis de pisciculture, des autorisations de vente, de transport, d'ensemencement, d'importation, d'exportation et du certificat de santé du poisson; b) les activités piscicoles qui ont un impact sur la faune du milieu naturel; c) la détermination et l'application de normes de qualité sur les stocks de poissons destinés au repeuplement et à l'importation;

4) le ministre de l'Agriculture exécutera les différents contrôles sanitaires dans les piscicultures privées, mais le ministre du Tourisme, de la Chasse et de la Pêche conserve seul la compétence en vue de l'application du règlement sur la protection de la santé des poissons et de la certification des pisciculture privées dont la production, en tout ou en partie est destinée au repeuplement;

5) le ministre du Tourisme, de la Chasse et de la Pêche émettra ou renouvellera le permis d'exploitation d'un établissement de pisciculture si le demandeur se conforme à la loi des Pêcheries, à la loi de la Conservation de la Faune et aux règlements qui en découlent, de même qu'aux critères de sélection pour l'émission de permis et d'autorisations apparaissant à l'annexe "A" et formant partie intégrante du présent protocole que le ministre de l'Agriculture du Québec s'engage à suivre;

6) le ministre du Tourisme, de la Chasse et de la Pêche ne pourra retirer un permis de pisciculture dont le détenteur se sera conformé aux exigences de l'item 5;

7) le ministre de l'Agriculture apportera aux lois et règlements de son ressort les modifications nécessaires pour rendre les piscicultures admissibles aux mesures d'assistance financière dispensées aux producteurs agricoles;

8) le ministre de l'Agriculture du Québec et le ministre du Tourisme, de la Chasse et de la Pêche établiront et développeront conjointement un programme de production et d'approvisionnement d'oeufs de poissons, pour fins d'élevage, à partir de géniteurs élevés en pisciculture.

Annexe au protocole d'entente entre le ministre de l'Agriculture du Québec et le ministre du Tourisme, de la Chasse et de la Pêche concernant la pisciculture.

Critères d'admissibilité à divers permis, diverses autorisations et au certificat de santé concernant la pisciculture privée.

A- Permis d'exploitation

1) Le permis de pisciculture sera émis en conformité avec les règlements de pêche du Québec déterminant les espèces de poissons dont l'élevage, le transport et le repeuplement sont permis dans chaque territoire;

2) les permis ne seront émis que s'ils sont recommandés par le ministère de l'Agriculture;

3) toute demande de permis devra être accompagnée d'un plan projet préparé ou approuvé par le ministère de l'Agriculture;

4) le ministère du Tourisme, de la Chasse et de la Pêche pourra procéder à l'inspection des lieux avant l'émission ou le renouvellement du permis d'exploitation d'un établissement de pisciculture;

5) le permis d'exploitation ne sera émis que si les installations sont en tout conformes aux exigences des lois et règlements administrés par les Services de Protection de l'Environnement et le ministère des Richesses naturelles.

B- Permis de transport

1) Le détenteur d'un permis d'exploitation d'un établissement de pisciculture de catégorie I peut émettre, à l'aide de la facture numérotée prescrite à cet effet, les autorisations suivantes:

a) Le transport de truites arc-en-ciel vivantes pour fins de consommation seulement;

b) le transport de truites mouchetées vivantes pour fins d'ensemencement et d'élevage, et le transport d'oeufs de truites mouchetées pour fins d'ensemencement seulement;

c) la possession de salmonidés d'élevage, capturés à la ligne dans un étang de pêche reconnu comme tel par le ministre du Tourisme, de la Chasse et de la Pêche; ces salmonidés doivent être morts au moment du départ de l'établissement et, de plus, les truites mouchetées ainsi capturées doivent être munies de l'étiquette prescrite à cet effet.

2) Tous les autres permis ou autorisations sont émis par le ministère du Tourisme, de la Chasse et de la Pêche.

C- Permis d'ensemencement, d'importation et d'exportation

L'émission du permis d'ensemencement, d'importation et d'exportation demeure sous la juridiction exclusive du ministère du Tourisme, de la Chasse et de la Pêche.

D- Certificat de santé

L'émission du certificat de santé du poisson, en vertu du règlement sur la protection de santé des poissons demeure sous la juridiction exclusive du ministère du Tourisme, de la Chasse et de la Pêche.

E- Généralités

1) La validité du permis d'exploitation se termine avec la fin de l'année du calendrier;

2) le permis d'exploitation n'est renouvelable que sur présentation au Service de Pisciculture du ministère du Tourisme, de la Chasse et de la Pêche et au ministère de l'Agriculture, avant le 31 décembre de chaque année, d'un rapport d'activités. Un chèque certifié ou mandat poste fait à l'ordre du ministre des Finances devra aussi être transmis au Service de Pisciculture du ministère du Tourisme, de la Chasse et de la Pêche;

3) le rapport d'activités soumis par le pisciculteur est un document de caractère strictement confidentiel; ce rapport se fait selon la formule prévue à cette fin et délivrée par le ministère du Tourisme, de la Chasse et de la Pêche;

4) le permis d'exploitation doit être affiché à l'établissement de façon visible;

5) le propriétaire d'un établissement de pisciculture est tenu de faire exécuter à ses frais tout traitement prophylactique prescrit par le ministère du Tourisme, de la Chasse et de la Pêche ou le ministère de l'Agriculture et de soumettre ses poissons à la quarantaine si celle-ci est décrétée par l'un ou l'autre de ces ministères;

6) toute importation dans la province de Québec de salmonidés ou d'oeufs de salmonidés doit respecter les exigences des règlements d'exécution de la loi sur les pêcheries en vigueur au Québec. Ce type d'importation fait présentement l'objet d'un ban et seul le ministère du Tourisme, de la Chasse et de la Pêche peut importer des oeufs de salmonidés;

7) tout officier du ministère du Tourisme, de la Chasse et de la Pêche et du ministère de l'Agriculture du Québec peut, en tout temps, effectuer sans préavis l'inspection d'un établissement de pisciculture.

APPENDIX D: SURVEY QUESTIONNAIRE

The following covering letter accompanied the survey questionnaire...

Name of manager
address

date

subject: Survey of aquaculture enterprises

The aquaculture division of the research branch of the Fisheries and Marine Service wishes to undertake a descriptive and analytical survey of aquacultural installations within the Quebec Region. This study will be carried out with the active participation of the Quebec Departments of Agriculture and Tourism, Fish and Game who both contributed to the preparation of the study plan.

The aims of this survey are as follows:

1) to complete the descriptive data on Quebec aquacultural enterprises;

2) to identify and define the environmental characteristics of the different geographical zones;

3) to identify the limiting factors of existing enterprises;

4) to identify the most important problems presently confronting fish culturists in the different regions of Quebec.

The analysis of these data will be of use:

1) to the fish culturist, in supplying him with accurate and comparative data on his own installation;

2) to the entire fish-rearing community, in supplying accurate information on the present state of pisciculture in Quebec, and on its social, economic and productive importance. This information will be of use for future planning in the aquacultural field;

3) to all governmental services directly or indirectly concerned with the rearing of fish;

4) to our own research organization in defining what the pisciculturists themselves conceive of as the most urgent problems which should be studied.

The survey will be conducted by our representative, Lars Hansen, who will be accompanied, for at least some of the interviews, by a representative of the Quebec Department of Agriculture. Mr. Hansen will contact you a few days prior to the site visit in order to make certain you are available.

We would appreciate your starting to answer the questions in the enclosed questionnaire. During his visit, Mr. Hansen will help you complete the questionnaire, and will carry out some tests on your water and if need be, collect pathological material for diagnostic purposes. He will attempt to answer your questions to the best of his ability.

Your collaboration is essential for the success of this survey, and we count on it.

Paul Montreuil
Research Branch
Aquaculture Division
Department of Fisheries and Oceans

SURVEY QUESTIONNAIRE

SURVEY OF AQUACULTURAL ENTERPRISES OF QUEBEC

I. Name of operation

Post Office address:
Telephone number:
Location:
County:
Township:
Lot number:
Watershed:
Type of licence:

II. Owners

Name (s) and address(es): Telephone number (s):

III. Years in operation:

IV. Number of employees, both full-time and part-time, including the manager:

SECTION 1

1. Which species do you raise? Please indicate the number you have at present in each category.

Species	Eggs, fry to 1 year	1 year	2 years and over
A- speckled trout			
B1- rainbow trout (spring)			
B2- rainbow trout (fall)			
C- brown trout			
D- cutthroat trout			
E- lake trout			
F- splake			
G- Atlantic salmon			
H- landlocked salmon (ouananiche)			
I- smallmouth bass			
J- largemouth bass			
K- bait fish			
L- carp			
M- other (specify)			

2. What are the sources of this year's stock and what are the quantities from each source?

A) Eggs from your own stock?
B) Eggs from a private hatchery? (Name):
C) Eggs from a government hatchery?
D) Stock purchased from other suppliers?
E) Wild stock, fish or eggs?

Species	A	B	C	D	E

3. How did you dispose of your production in 1977? Please specify the number and the categcry (A-F) for each age class.

A) Pond fishing
B) Stocking a) clubs
b) private ponds
C) Sales to other hatcheries
D) Consumption
E) Bio-assay stock
F) Bait

Species	Fry	Fingerlings (under 1 year)	1 year	2 years and over	Eggs

4. What do you estimate your loss per species and age class was in 1977?

A) 0-25%
B) 25-50%
C) 50-75%
D) 75-100%

Species	Fry	Fingerlings (under 1 year)	1 year	2 years and over	Eggs

5. If you produce your own eggs, how many brood fish do you have of each sex and age class?

Species	1 year	2 years	3 years

6. What was your total production per species in 1977?

Species	Weight

SECTION II

1. What have been the principal causes of mortality in your installation?

Causes	Remarks	Percentage of production lost
( ) Accidents		
( ) Predation		
( ) Disease		

2. Did you use any chemicals or drugs for the prevention or treatment of disease?

If you did use chemicals or drugs...

a) What symptoms did the fish have?

b) What species and ages were treated?

c) What time of the year was this treatment used at?

d) What treatment was used?

e) Who prescribed or recommended the treatment?

f) Dose?

g) Method and schedule of application?

h) Number of treatments given and their duration?

i) What were the results?

3. Have you ever had your fish examined by an expert in fish diseases? If so, why and what were the results?

4. What feed(s) do you use? Are there specific reasons for your choice?

5. How much do you use of each brand per year?

SECTION III

1. What are the sources of water available to you? For each different source, please indicate:

   - the temperature range.
   - the maximum and minimum flow of water used for culture.
   - the maximum and minimum flow of water available

Source	No	Temp. range	Water used	Water available	Notes
A) Springs					
B) Wells (artesian)					
C) Wells (pumped)					
D) Brooks					
E) Lake					
F) Stream					
G) Other (specify)					

COMMENTS:

2. Have you ever had your water tested? If so, what was it tested for and what were the results? Please, also indicate who performed the test.

Source of water	Test	Results	Tested by

3. Do you recycle any water? If so, please describe your system.

4. Do you heat or cool your water? If so, how?

5. Do you aerate or de-gas your water? If so, how?

6. Do you filter your incoming water? If so, please describe your system.

7. Where is your water discharged? Do you treat the discharged water?

8. How many pumps do you have and what is their capacity?

_____

_____

_____

_____

9. Do you possess a back-up system in case of break-down?

Alarms
Emergency power generator
Gasoline pumps
Others

10. What types of upstream activities are there above your installation?

Pisciculture
Forestry
Agriculture
Mining
Industry
Residences
Others

SECTION IV

Describe your equipment.

	Troughs	Tanks	Raceways	Ponds and lakes	Others (e.g. incubators)
Number					
Material					
Size					
Volume					
Water flow					
Hourly exchange rate					
Source					

SECTION V

1- With your present equipment, do you feel you are exploiting the full potential of your installation?
2- Do you presently have all the information needed to calculate your production costs and profit margin?
3- Do you envisage changes in your market, and consequently in your type of production following the new regulations with respect to declubbing and aquacultural zoning?
4- If you were offered technical and financial aid, what improvements would you make to your hatchery?

A- Hydraulic improvements

- excavation
- draining
- pond excavation
- lake excavation
- other (specify)

B- Capital improvements

- building
- purchase of auxiliary generator
- purchase of land
- other (specify)

SECTION VI

What are the most important problems presently facing fish farmers in Quebec?

What steps could be taken to help remedy those problems?

What governmental actions and services do you feel could be most helpful to the industry?

APPENDIX E: QUEBEC GOVERNMENT DEPARTMENTS INVOLVED IN REGULATING AND LICENSING AQUACULTURE OPERATIONS.

Ministère des Loisirs, de la Chasse et de la Pêche
Service de pisciculture
Place de la Capitale
150, Boul. St-Cyrille est
Québec, Qué.
G1R 4Y1 Tél: (418) 643-4664

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation
Service des productions animales
Division de l'aquiculture
200-A, Chemin Ste-Foy
Québec, Qué.
G1R 4X6 Tél: (418) 643-7575

Ministère de l'Environnement
Direction générale des recherches et de la planification
2360, Chemin Ste-Foy
Québec, Qué.
G1V 4H2 Tél: (418) 643-2006

Ministère de l'Energie et des Ressources
Service du milieu hydrique
1640, Boul. de l'Entente
Québec, Qué.
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